SECTION 3

DEPARTMENT OF COMMERCE WEATHER PROGRAMS
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is the principal meteorological agency of the Federal government. By law, NOAA is responsible for reporting the weather of the United States, providing weather and flood warnings and forecasts to the general public, developing and furnishing applied weather services, and recording the climate of the United States. This mission is carried out within NOAA by the National Weather Service (NWS); the National Environmental Satellite, Data, and Information Service (NESDIS); the Office of Oceanic and Atmospheric Research (OAR); the National Ocean Service (NOS); and the NOAA Marine and Aviation Operations (NMAO).

NATIONAL WEATHER SERVICE

NOAA's National Weather Service (NWS) has the principal responsibility for planning and operating the basic climate, hydrologic, and weather services and certain specific applied services. The NWS provides climate, water, and weather warnings and forecasts for the U.S., it's territories, adjacent waters, and ocean areas to help protect life and property and enhance the national economy. NWS data and products form a national information data base and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. In support of this mission, NWS:

- Issues warnings and forecasts of weather, flood, Great Lakes, coastal and ocean conditions.
- Observes and reports the weather and the river and ocean conditions of the U.S. and its territories.
- Develops and operates national meteorological, hydrological, climate, space weather and oceanic service systems.
- Performs applied meteorological, hydrological, space environmental and climate research.
- Assists in developing community awareness and educational materials and programs concerning weather-related natural disasters.
- Participates in international hydrometeorological and space weather activities, including the exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

The basic enabling legislation and authority for weather services are summarized as follows:

- Organic Act of 1890 created the United States Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the United States Weather Bureau to enter into cooperative agreements for providing agriculture weather services.
- Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.
- Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for providing weather observations and services to aviation.
- Reorganization Plan 2 of 1965 placed the "National Weather Service" in the newly created Environmental Science Services Administration (ESSA).
- Reorganization Plan 4 of 1970 made the NWS a part of the newly created National Oceanic and Atmospheric Administration (NOAA).
- International Convention for the Safety of Life at Sea (SOLAS) agreement to which the U.S. is signatory. This sets international policy for safer shipping and cleaner seas. The U.S implements the convention through Executive Order 12234 of Sept. 3, 1980 -- *Enforcement of the Convention for SOLAS*. Among the obligations of the agreement is to provide meteorological warnings and forecasts to ships at sea using charts and radio messages.

SERVICES

NWS provides climate, water, weather and space weather prediction services; including watches, warnings, advisories, and forecasts 24 hours a day, seven days a week. These services are provided through a national network of 122 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), and the nine centers of the National Centers for Environmental Prediction (NCEP). These offices collect data, prepare local warnings and forecasts, and disseminate information to the public both nationally and internationally through NOAA Weather Radio, satellite-based telecommunication systems, radiofacsimile, the media and the internet. Forecast and warning services prepared at WFOs are derived in part from prediction guidance prepared by the 13 RFCs and the nine NCEP centers. These centers are: Hydrometeorologi-

cal Prediction Center, Storm Prediction Center, Aviation Weather Center, Environmental Modeling Center, Tropical Prediction Center, Climate Prediction Center, Space Environment Center, Ocean Prediction Center, and NCEP Central Operations.

Continually improving the accuracy, timeliness, and accessibility to prediction services is largely a result of research and development both within the NWS and externally from universities and private corporations.

PUBLIC WEATHER SERVICES

NOAA's NWS Public Weather Service Program provides forecast, warning, and response services to the public, private meteorological firms, broadcast meteorologists, and NWS partners who are responsible for public safety. These partners include Federal, state, and local emergency managers and planners. NWS forecasters issue short-duration watches and warnings for severe weather, such as tornadoes and severe thunderstorms, as well as long-duration watches, warnings, and advisories for hazardous winter weather conditions, high wind events, dense fog, and temperature extremes. NWS forecasters support several health related programs such as Air Quality, Heat Health, and the Ultraviolet Index (UVI). Ground based ozone concentration forecasts and an experimental smoke forecasting tool are now being produced for the CONUS. A nationwide air quality forecast capability including concentrations of aerosols, particulate matter, and other pollutants is under development. Heat Health Watch Warning Systems (HHWWS) have been developed for select cities to provide advance notice of excessive heat events that produce the greatest number of weather-related deaths. These guidance systems will be expanded to other cities as resources are made available. Also, in partnership with the Environmental Protection Agency (EPA), a new climatologically based UV alert is being produced for the entire nation. The Branch serves as the primary focal point for collaboration with Federal transportation agencies on weather issues related to surface transportation, with Federal, media, and private entities on the UVI, and with the World Meteorological Organization on the provision of public weather services to the international community. Additionally, NWS forecasters provide meteorological support both on-site and from WFOs for terrorist acts and other homeland security concerns, as well as accidental releases/spills of hazardous chemical, biological, or radioactive materials.

Since 2004, the National Weather Service has created, and made readily available, forecasts in digital formats. NWS forecasters use their expertise to maintain an up-to-date digital forecast database of sensible weather elements. This information is stored in the National Digital Forecast Database (NDFD). Output from NDFD is available in the form of web graphics available over the Internet, in gridded binary format (GRIB2) available via anonymous file transfer protocol, or in XML via an experimental web service. NDFD data can also be converted to a file format that can be used with Geographical Information Systems (GIS). NDFD includes the following operational forecast elements: Maximum Temperature, Minimum Temperature, 12-Hour Probability of Precipitation, Temperature, Dew Point, Weather, Wind Speed and Direction and derived elements Relative Humidity and Apparent Temperature. Experimental forecast elements include Quantitative Precipitation Forecast (QPF), Snow Amount, Significant Wave Height and Sky Cover. For more detailed information on NDFD, please see http://www.nws.noaa.gov/ndfd/.

AVIATION WEATHER SERVICES

The NWS provides a broad range of services in support of the aviation community. The WFOs prepare Terminal Aerodrome Forecasts (TAFs) four times a day, with amendments as needed, for more than 590 public-use airports in the U.S. and it's territories in the Caribbean and Pacific. These offices also produce about 241 individual route-oriented forecasts three times a day for the 48 contiguous states and over the Pacific Ocean.

NCEP's Aviation Weather Center (AWC) and the Alaska Region's Alaska Aviation Weather Unit (AAWU), and WFO Honolulu, HI prepare area forecasts three or four times daily describing general aviation weather conditions over the lower 48 states, the Gulf of Mexico, Caribbean, Alaska, Hawaii and coastal waters respectively. These three specialized offices also issue in-flight advisories and warnings of hazardous weather conditions associated with thunderstorms, icing, turbulence, and strong, low level winds. The AWC also prepares forecasts of significant aviation weather over the continental U.S. four times a day for flight levels from the surface to 25,000 feet.

NWS Center Weather Service Units located in each of the 21 FAA Air Route Traffic Control Centers provide direct meteorological support to en route centers, Terminal Radar Approach Controls, airport towers, and Automated Flight Service Stations.

The NWS provides a service to international aviation as one of the International Civil Aviation Organization's (ICAO's) two World Area Forecast Centers. NCEP's Environmental Modeling Center supplies global gridded model data of temperature, winds, and humidity twice a day for flight levels from 5,000 to 45,000 feet. The AWC prepares forecasts four times a day of globally significant thunderstorms, tropical cyclones, severe squall lines, moderate or severe turbulence and icing, and cumulonimbus cloud associated with the above, from 25,000 to 63,000 feet. The forecast charts also

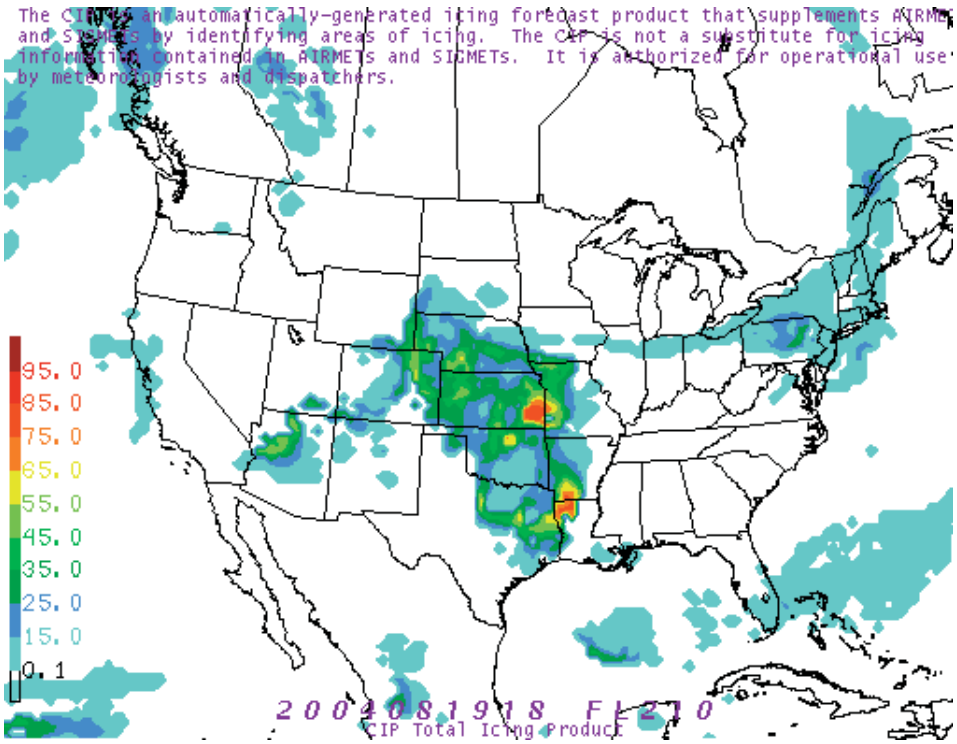


Figure 3-DOC-1. Current Icing Potential (CIP) Product. The FAA's Aviation Weather Research Program and the NWS developed this graphical icing product, updated every 3 hours, and available for user selected altitudes across the contiguous U.S.

include information on volcanoes, radiological releases, jet streams and tropopause heights. This information is transmitted by the International Satellite Communications System with coverage in the Americas, Caribbean, western portions of Europe, the Pacific, and eastern Asia.

Within the framework of the international airways volcano watch, the NWS and NCEP share management responsibility for operating the Volcanic Ash Advisory Centers (VACC) in Washington state and Anchorage, Alaska.

The NWS, working closely with the FAA's Aviation Weather Research Program, developed new experimental and operational forecast products designed to improve aviation hazard forecast capabilities zero to six hours into the future (Figure 3-DOC-1).

New icing and turbulence products for meteorologists and end users became operational in FY 2004. Improved software tools to increase the number of terminal airports covered by a forecast are also under development.

MARINE WEATHER SERVICES

The NWS Marine Weather Program is the lead for the nation's marine and coastal weather services. Programs include warnings, forecasts, and advisories for coastal waters, offshore, high seas, and near-shore and open waters of the Great Lakes. It leads programs for tropical cyclone, coastal flood, severe convective coastal weather, and coastal hazards such as high surf, rip currents, and tsunamis. NWS forecasters at 46 coastal and marine WFOs, in collaboration with NCEP's Ocean Prediction Center and Tropical Prediction Center, provide a range of weather services focused on the expanding and weather-sensitive U.S. coastal population and those responsible for its safety.

The program develops plans, policy and procedures for the delivery of marine and coastal weather products and services from the coastal WFOs, the Ocean Prediction Center, the Tropical Prediction Center, and the Central Pacific Hurricane Center. It ensures marine and coastal forecast training needs are met. The program works with the Office of Science and Technology to prioritize tropical, marine and coastal science and technology development and approve new or improved product designs, and with the Office of Operational Systems to ensure the collection of marine and coastal observations and the delivery of marine and coastal products to users. The program creates internal and external partnerships, collects and validates marine and coastal service and mission needs, solicits feedback on products and services and validates whether these needs are met.

The program works with NOAA's NESDIS, the U.S. Navy and the U.S. Coast Guard (USCG) to provide ice warning and advisory services through the joint National Ice Center; with the Navy, the USCG, the U.S. Maritime Administration, and the Corps of Engineers to safely operate the nation's Marine Transportation System; with the Department of Defense, Federal Emergency Management Agency, and Corps of Engineers to provide tropical cyclone services; with the USCG, Navy, Air Force, and private entities to disseminate weather to mariners; with NOAA's National Ocean Service (NOS) on the PORTS and TIDES programs; and with the World Meteorological Organization to provide services to the international community. It also works in cooperation with NOAA's Office of Response and Restoration, the Department of Defense, and Department of Homeland Security for forecasting services for hazardous material spills, marine area search, rescue, and recovery operations, and security needs.

FIRE/ALL HAZARD WEATHER SERVICES

NOAA's NWS offices provide rou-

tine pre-suppression and wildfire weather support to Federal and state land management agencies. NWS forecasters provide routine fire weather forecasts, forecast support for the National Fire Danger Rating System, and site specific forecasts during the local fire season over roughly three-quarters of the nation. The NWS deploys a national cadre of specially-trained Incident Meteorologists (IMETs) to large wildfires and coordination centers for on-site weather support. IMETs use weather instrumentation, telecommunications, and display equipment to aid in on-site forecast preparation and briefings. In the early morning, NOAA's National Centers for Environmental Prediction's Storm Prediction Center issues outlooks for days 1, 2 and 3 to 8, that highlight areas with critical and extremely critical fire potential based on the state of the fuels (trees, brush, grasses), and critical weather parameters. Areas where significant lightning activity accompanied by less than 0.1 inch of precipitation (dry lightning) is forecast are also highlighted. Additionally, NWS forecasters provide forecasts in response to hazardous material incidents or Incidents of National Significance (such as the Columbia Recovery effort).

TSUNAMI WARNINGS

Tsunami watches, warnings, and information bulletins for the Pacific Ocean and Hawaii are prepared by the Richard H. Hagemeyer Pacific Tsunami Warning Center in Ewa Beach, Hawaii, and for west coast of the continental U.S. and Alaska by the West Coast/Alaska Tsunami Warning Center in Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observatories, sea-level observing stations, and deep-ocean tsunami detection buoys which operate on a cooperative basis. The centers use these data to prepare and disseminate watches, warnings, and information bulletins to international customers, WFOs, Federal and state disaster agencies, military organizations, private broadcast media, and other agencies involved with warning the public.

CLIMATE SERVICES (CS)

Climate prediction products and other services relate to the period of week two out to one year, including seasonal forecasts and hazard assessments. The NWS's Climate Prediction Center produces a suite of products covering these periods. The climate services program provides the strategic vision for climate services at NWS, oversees the program including the expanded regional and local climate services programs, and serves as steward of the climate observing system. It maintains strong ties with other countries; across NOAA lines, specifically through the NOAA Climate Office; with Federal agencies; the university community; and the private sector and encourages collaborative arrangements among the Regional Climate Centers (managed by NOAA/NESDIS), the State Climatologists, and NWS WFOs and regional headquarters to tailor climate forecasts for local users.

HYDROLOGIC SERVICES

The 122 WFOs, 13 River Forecast Centers (RFCs), and NCEP's Hydrometeorological Prediction Center (HPC) work as a team to provide hydrologic forecast and warning services which minimize loss of life and property damage from flooding and to meet the water service needs of our Nation. RFC hydrologists use a modeling system called the NWS River Forecast System (NWSRFS) to produce forecast time series of discharges or river stages at approximately 4,000 locations along the nation's rivers. HPC provides the quantitative precipitation forecasts serving as the primary forecast input for NWSRFS. RFCs also provide long-term water supply forecasts used by water managers in the western U.S., where decisions about water allocation and use are particularly critical now, with much of the West still feeling the effects of a long-term drought.

WFOs work cooperatively with the RFCs to monitor the major river systems around the clock. Using RFC guidance, advanced Doppler radar (NEXRAD) and telemetered rain gauge observations, WFOs continuously monitor the threat of flash flooding and urban flooding to provide timely flood watches and warnings to protect life and property.

Partnerships with a variety of Federal, state and local agencies are critical to NOAA's NWS Hydrologic Services Program. For example, the NWS works very closely with the United States Geological Service (USGS), the United States Army Corps of Engineers, the Natural Resources Conservation Service (NRCS), the Bureau of Reclamation, and the Bureau of Land Management on a variety of water related issues including stream gauging, support of flood fighting activities, river and water supply forecasting, and water management. River stage observations and stage-discharge relationships provided by the USGS are critical to warning and forecast operations for the Nation's rivers. The NRCS furnishes snow measurements that are combined with advanced snow modeling and analysis provided by NOAA's National Operational Hydrologic Remote Sensing Center to support joint NWS-NRCS water supply forecasting in the western U.S.

The NWS is implementing the Advanced Hydrologic Prediction Service (AHPS) to provide hydrologic forecasts with lead times ranging from minutes to months. AHPS builds on the existing NWS infrastructure, including AWIPS, NEXRAD, and NWSRFS. AHPS also provides Ensemble Streamflow Prediction, a feature that allows the NWS to quan-

tify forecast uncertainty. This lets decision makers apply risk-based analyses as they respond to flooding, and as they try to balance competing demands on water supply, especially during periods of drought.

Flash floods, typically caused by intense, small-scale convection, are the leading cause of flood fatalities. Another AHPS capability, known as Flash Flood Monitoring and Prediction (FFMP), combines high-resolution radar rainfall observations with Geographic Information System (GIS) technology to provide more accurate and much more precise flash flood forecasts. The added precision provided by FFMP greatly reduces the false alarm rate of flash flood forecasts, making them more credible and leading to better public response, which will ultimately save lives.

AHPS services are provided as a suite of Web-based products (weather.gov/ahps), that feature user-friendly menus and maps which allow users to zoom in to areas of interest. Clicking on an area of interest on the national map brings the user to a map of the NWS WFO serving that area which provides more detailed information on river conditions. AHPS also opens opportunities to improve NOAA's analysis and forecast capabilities related to coastal water conditions, through joint efforts with other components of NOAA (e.g., National Ocean Service, Office of Oceanic and Atmospheric Research).

OBSERVATIONS

Observations form the basis for forecasts and the monitoring and evaluation of the environment. Differing applications and requirements are associated with each of these functions. Forecast applications associated with watch and warning functions must be served immediately, while real-time availability is not a significant factor for climate monitoring. The range of differing applications will dictate how future instrument deployments will be conducted. This poses a constant challenge to the optimization of resources placed into in-situ and remotely sensed observation platforms.

The fundamental application of observations is to deliver better products and improve services. This demands the link between improved services and observing systems be well defined. We need to determine the gaps in observations to meet varied requirements, emphasizing the importance of metadata and sensor calibration continuity. Coordinated efforts within the Federal community throughout all aspects of observations development, dissemination and use are needed for efficient utilization of resources.

The NWS approach for improving observations consists of several efforts:

• Make better use of data from observing systems that currently exist;

• Extend the system life of current observing systems to postpone technical obsolescence;

• Replace obsolete observing systems;

• Implement new observing tech-

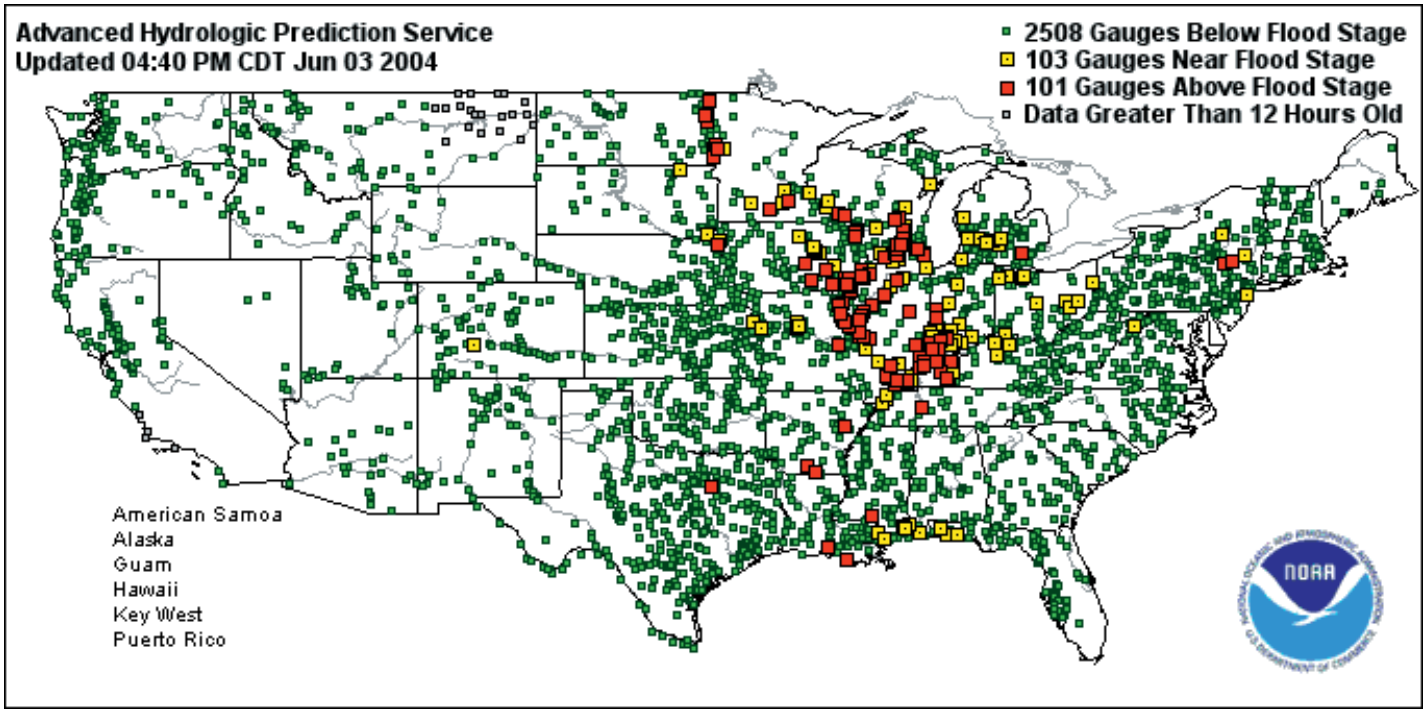


Figure 3-DOC-2. Map showing status of river conditions throughout the Nation. This map is included on the primary AHPS Web page and it provides access to more detailed local information on river conditions, including observations and forecasts at specific locations along rivers, as well as expected impacts that could result from flooding.

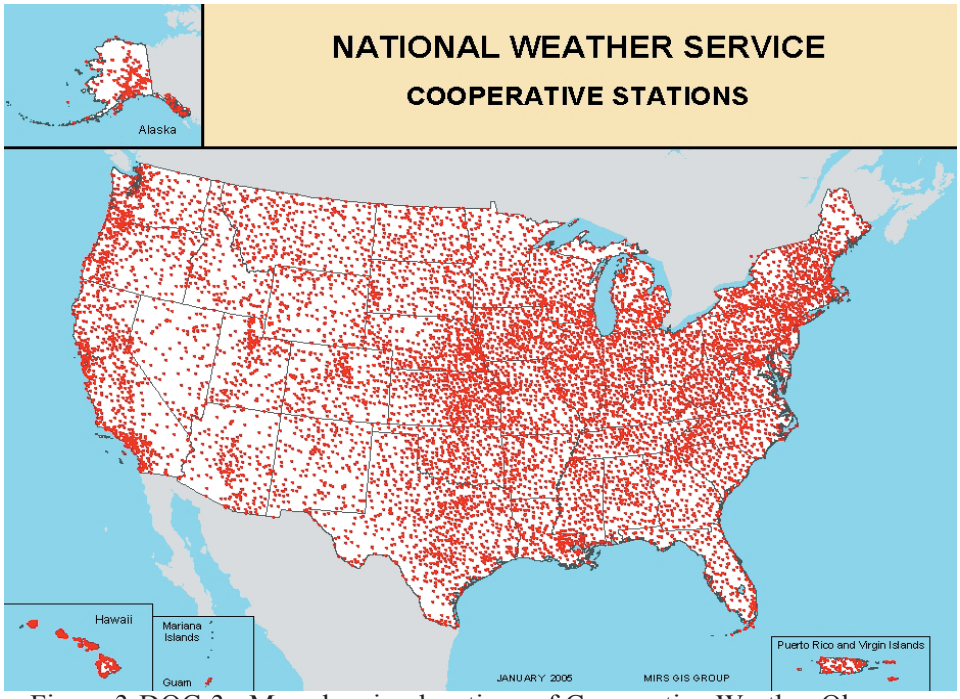


Figure 3-DOC-3. Map showing locations of Cooperative Weather Observer Network (COOP). Interactive web site can be found at *http://www.nws.noaa.gov/om/coop/wfo-rfcmap.htm*

nologies and communication systems that better meet the data needs of our customers; and

• Strengthen the link between user requirements and technology research and development.

The NWS manages programs that produce observations in support of a wide range of customers, such as the aviation, climate monitoring and research communities. As part of its responsibility, the NWS inspects all surface weather observing stations and certifies equipment and observers. NWS Headquarters establishes policy for observations and standards and coordinates with other Government agencies and international organizations.

NOAA'S COOPERATIVE WEATHER OBSERVER NETWORK (COOP)

THE COOP is the Nation's largest and oldest weather network. Modernization of the COOP under NERON is consistent with the President's Climate Change Research Initiative, providing a richer source of data to improve weather, water and climate forecasting and to contribute to climate change research. The COOP is the primary source for monitoring U.S. climate variability over weekly to interannual time frames. These data are also the primary basis for assessments of century-scale climate change. The modernized network will add to NOAA's vision of an-end-to-end monitoring program that "takes the temperature" of the earth's systems.

NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

NCEP delivers analyses, guidance, forecasts and warnings for weather, ocean, climate, water, land surface and space weather to the nation and world. NCEP provides science-based products and services through collaboration with partners and users to protect life and property, enhance the Nation's economy and support the Nation's growing need for environmental information. Each service center depends on the observational infrastructure, the data assimilation systems, the numeric modeling function, and the application of model output statistics to produce value added forecast guidance products for NWS field offices and other users.

NCEP is organized into seven science-based, service-oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models -- the basis for NWS predictions.

Storm Prediction Center

The Storm Prediction Center (SPC) focuses on hazardous weather events, such as severe thunderstorms, tornadoes, extreme winter weather, fire weather, and excessive precipitation with emphasis on the forecast period that ranges from 2-8 hours to the next 6 to 72 hours. All Tornado and Severe Thunderstorm Watches issued anywhere in the contiguous U.S. come from the SPC in collaboration with local NWS Forecast Offices. Also, the SPC prepares Mesoscale Convective Discussions which are technical explanations of developing mesoscale features and their impact on hazardous weather. For longer time periods, the SPC produces the Convective Outlook which is the one-, two- or three-day forecasts of the probability and intensity of both non-severe and severe thunderstorms (including tornadoes). The SPC also issues one- and two-day Fire Weather Outlooks for the contiguous U.S. defining areas with critical, extremely critical and dry thunderstorm fire conditions and potential for defined areas.

Hydrometeorological Prediction Center

The Hydrometeorological Prediction Center (HPC) provides forecast, guidance, and analysis products and services (1) to support the daily public forecasting activities of the NWS and its customers, and (2) to provide tailored support to other government agencies in emergency and special situations. As part of this mission, HPC prepares Quantitative Precipitation

Forecasts (QPF) used by the RFCs to develop local river and flood forecasts and by WFOs to develop local rainfall, snow and ice forecasts. The HPC provides special QPFs and coordinates with other Federal agencies, such as the Federal Emergency Management Agency (FEMA), during major flood events. The HPC also provides an array of analyses and forecasts out to seven days of frontal systems, pressure patterns, temperature, and precipitation for use by WFOs and the private weather community. Additionally, HPC serves as the backup to the National Hurricane Center.

Aviation Weather Center

The NCEP experts for aviation meteorology are concentrated at the Aviation Weather Center (AWC). The AWC provides weather warnings, advisories and forecasts to the aviation community under an international agreement through the International Civil Aviation Organization. The AWC provides wind, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and en route aircraft operations for the U.S., the Gulf of Mexico, the Caribbean Sea, the Atlantic and Pacific routes in the Northern Hemisphere and some routes in the Southern Hemisphere.

Environmental Modeling Center

The Environmental Modeling Center (EMC) improves NCEP's numerical climate, water, and weather predictions through data assimilation and computer modeling. To provide mesoscale predictions (thunderstorms, hurricanes, tornadoes, blizzards, etc.), ocean predictions and global weather and climate predictions, EMC develops, adapts, improves, and monitors data assimilation systems and global, regional and mesoscale models of the atmosphere, land surface, ocean, and atmosphere/ocean/land systems. The EMC uses advanced modeling methods developed internally and cooperatively with universities, the international scientific community, NESDIS, NOAA laboratories, and other government agencies. As an example, EMC is a partner in the NASA/NOAA Joint Center for Satellite Data Assimilation (JCSDA) designed to accelerate the use of research and operational satellite data in NCEP operational models. The EMC integrates research and technology through collaborative model development projects. These interactions serve as an efficient and effective interface between NCEP and the scientific community that develop ideas, numerical models, and forecast techniques to implement model improvements and improve NWS products. The EMC conducts applied research and technology transfers and publishes research results in various media for dissemination to the world meteorological, oceanographic, and climate community. EMC also participates in ongoing interactive research programs such as the USWRP Hurricane at Landfall project and the community Weather Research and Forecast (WRF) model. Furthermore, EMC is participating in the Winter Storm Reconnaissance Program in the Pacific through targeted observations aimed at improving forecasts across the country. EMC efforts with collaborative development have resulted in improvements to mesoscale and global models, as well as advancements in hurricane track forecasts, climate forecasts and air quality forecasts.

Climate Prediction Center

The Climate Prediction Center (CPC) provides operational monitoring and prediction of global and regional climate variability, with emphasis on applied research and partnerships, to improve understanding of the global climate system, weather and climate links, extremes and trends. CPC develops and maintains data bases for determining current and historical climate anomalies and trends, and provides analyses and assessments of their origins and linkages to the global climate system. CPC products and services cover time scales ranging from next week (days 6-10) to seasons and out to a year in advance, and cover land, ocean, and atmosphere extending into the stratosphere. CPC's products include probabilistic long range outlooks for temperature and precipitation, the multi-agency U.S. Drought Monitor (a drought outlook), and El Niño Southern Oscillation (ENSO) discussions and outlooks, among many others. WFOs, as well as the public, private industry, and the national and international research community use CPC products and climate services.

Space Environment Center

The Space Environment Center (SEC) provides national and international forecasts, alerts, and warnings of extraordinary conditions in the space environment, solar radio noise, solar energetic particles, solar X-ray radiation, geomagnetic activity, and conditions of stratospheric warming. The SEC observes, assesses, and predicts activity in the space environment to promote public safety and to mitigate economic loss that could result from disruption of satellite operations, communications and navigation systems, and electric power distribution grids. The SEC issues to the public, its U.S. Air Force partners, and vendors of value-added services specific predictions of the space weather activity level for the next three days and more general predictions up to several weeks in advance, as well as weekly summaries of observed solar terrestrial conditions. SEC serves as the international World Warning Agency for the International Space Environment Service (ISES). It exchanges international data- solar wind, X-ray, sunspot, corona, magnetic, and ionospheric measurements-in real-time and, from these data, provides and meets additional specific needs of other government agencies. SEC distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use.

Ocean Prediction Center

The Ocean Prediction Center (OPC) provides atmospheric and oceanographic warning, forecast, and analysis products and services for the North Atlantic and North Pacific (north of 30 degrees) as part of the NWS mission of protecting life and property and enhancing economic opportunity (Figure 3-DOC-4). As part of this responsibility, OPC handles U.S. international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). The OPC provides weather and sea state warnings and forecasts for the offshore waters of the U.S. and the high seas of the Northern Hemisphere, north of 30 degrees, for planning and operational purposes. OPC warnings and products go directly to ships and are vital for the protection of life and property at sea, and enhancement of the economy. The OPC also coordinates forecasts with and provides forecast guidance to WFOs with coastal responsibilities. The OPC, the Tropical Prediction Center (TPC), HPC, and WFO Honolulu, HI collaborate daily to produce unified and seamless surface weather analyses covering from 30 degrees South to the North Pole, and from East Asia across the Pacific and Atlantic to Western Europe and Africa.

Tropical Prediction Center/National Hurricane Center

The NCEP experts in the area of tropical meteorology are concentrated in the Tropical Prediction Center (TPC)/National Hurricane Center (NHC). TPC/NHC services include public and marine advisories, watches, and warnings for tropical cyclones in the North Atlantic and eastern North Pacific hurricane basins including the portions of the coastline threatened by such storms. In addition, TPC forecasters provide marine analyses and forecast products for the same areas of responsibility, south of 30 degrees north latitude and a portion of the southeast Pacific. TPC warnings and products go directly to ships and are vital for the protection of life and property at sea, and enhancement of the economy. The TPC/NHC provides guidance, coordination, and tropical weather expertise to WFO forecasters, the media, and private industry.

NCEP Central Operations

The NCEP Central Operations (NCO) is responsible for NCEP operations, including access to real-time data, and its quality control and use in numerical weather prediction systems, as well as the workstations used by NCEP forecasters to access model output and other data necessary for producing guidance products. The NCO provides management, procurement, development, installation, maintenance, and operation of all computing and communications related services that link individual NCEP activities together. The NCO is the focal point for establishing and executing policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO maintains and manages the supercomputer and runs the computer applications that generate all NCEP model products. The NCO leads the technical transition between the research and development of numerical weather and climate prediction models and their operational use on the NCEP computer systems. In addition, NCO provides 24-hour information services and operational support for NCEP computing systems, including the network which ties together internal NCEP communications, NWS high performance computer systems, forecaster workstations, personal computers and a user service that support all NCEP centers. Since an upgrade to NCEP's main computer systems and facilities in 1999, and throughout subsequent upgrades, NCO has delivered NCEP model forecasts and products to its users with a high degree of reliability and timeliness.

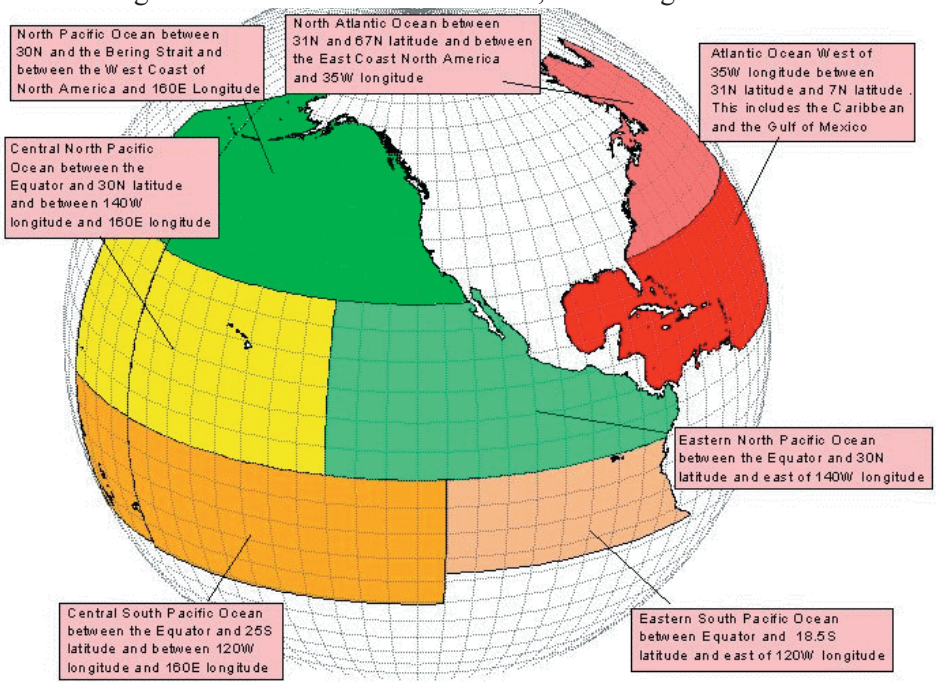


Figure 3-DOC-4. United States High Seas Forecast Areas of Responsibility.

Other NWS Offices with National Responsibilities

In addition to the NCEP centers, there are two other offices that provide National products. They are the Alaska Aviation Weather Unit and the WFO Honolulu/Central Pacific Hurricane Center.

Alaska Aviation Weather Unit. The Alaska Aviation Unit (AAWU) provides wind, temperature, and flight hazards (e.g., icing, turbulence) fore-

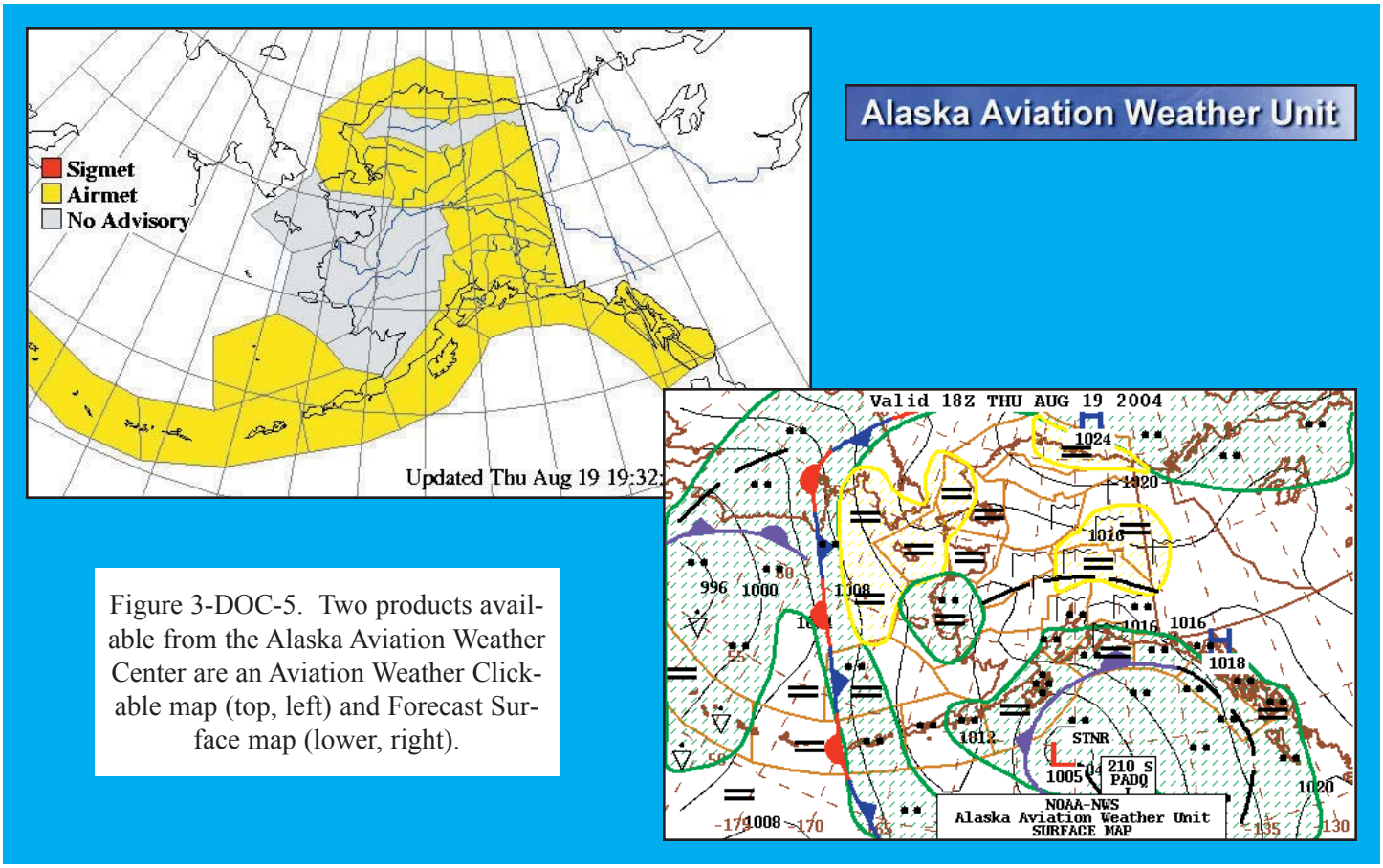


Figure 3-DOC-5. Two products available from the Alaska Aviation Weather Center are an Aviation Weather Clickable map (top, left) and Forecast Surface map (lower, right).

casts for flight planning and enroute aircraft operations for Alaska and surrounding areas (Figure 3-DOC-5).

WFO Honolulu/Central Pacific Hurricane Center. WFO Honolulu/Central Pacific Hurricane Center (CPHC) provides products in aviation, marine, and tropical cyclone areas. In aviation, WFO Honolulu provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for the central north Pacific from 140 degrees W to 160 degrees E longitude and in the Oakland Flight Information Region south of 30 degrees N latitude through ICAO international agreement. The office handles international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). WFO Honolulu provides weather and sea state warnings and forecasts for the high seas of the central north and south Pacific south of 30 degrees N latitude. CPHC issues tropical cyclone advisories, forecasts, watches, and warnings for the central north Pacific including Hawaii.

SUPPORTING RESEARCH

The NWS conducts applied research, building upon the more basic research conducted by NOAA laboratories and the academic community. Applied meteorological and hydrological research is integral to providing more timely and accurate weather, water, and climate services to the public.

METEOROLOGICAL RESEARCH

The NWS conducts meteorological research to develop, test, evaluate, and improve numerical models and analysis/forecast techniques for weather and climate prediction including:

- Techniques for predicting mesoscale phenomena (e.g., heavy precipitation, tornadoes, and severe thunderstorms).
- Models to improve hurricane tracking, hurricane probability estimates, and tropical analyses.
- Storm surge models to assist in developing hurricane evacuation plans for additional coastal basins.
- Techniques to improve prediction of seasonal to interannual climate variability and their impacts on weather variability.

HYDROLOGIC RESEARCH

The NWS develops, implements and operationally supports improved hydrologic, hydraulic and hydrometeorological models and manages hydrologic data and enhanced quality control procedure to support national flood and water resources forecasting. Research encompasses the following areas:

- Improvements to the Ensemble Streamflow Prediction (ESP) system and its complementary models in the NWS River Forecasting System. Research, development and implementation of improved ESP procedures which improve forecast accuracy and quantify uncertainty at all time scales.
- Specialized flood and flash flood forecasting procedures using linked

hydrologic, hydraulic and meteorological models. Major research areas include developing distributed hydrologic models that use high resolution precipitation data from the NWS radar network, improvement of cold region processes in watershed models, and assimilation of data to improve initial conditions. Highly specialized hydraulic models for routing river flows will also provide information for generating maps of inundated areas.

• Development of improved multisensor precipitation estimates for input estimates for input into operational hydrologic and atmospheric models. Radar, rain gauge and satellite rainfall estimates are merged to produce optimum rainfall analyses.

• Development of verification methods to assess the added-value of new science and technology to the customer.

SPACE WEATHER RESEARCH

Research and development at SEC emphasizes understanding of the fundamental physical processes governing the regime from the solar surface, through the interplanetary medium, into the magnetospheric-ionospheric regions, and ending in Earth's upper atmosphere. These processes are manifest in the climatology and disturbances of Earth's magnetic field, the ionosphere, the charged particle populations at satellite orbits, and the atmospheric density at high altitudes (including low-Earth orbit). This applied research is focused on areas where advanced applications can be devised and prototyped to improve the specification and forecast of conditions in the space environment by developing and implementing models and indices, as well as by obtaining and processing new observations.

• Developing of the first dynamic, global ionospheric model to use ensemble Kalman filter techniques to assimilate data every 15 minutes. Disparate data from widely dispersed sources will enable the model output to be useful to radio-communicators and Global Positioning System (GPS) and Loran users.

• Developing of models to characterize and predict geomagnetic storm intensity development, spatially and temporally.

SUPPORT FOR COLLABORATIVE RESEARCH WITH THE ACADEMIC COMMUNITY AND OTHER PARTNERS

The Collaborative Science, Technology, and Applied Research (CSTAR) program was established to bring NWS-supported collaborative activities with the academic community into a structured program and to create a cost-effective transition from basic and applied research to operations and services. The CSTAR Program issues requests for proposals through which colleges and universities compete for 1-3 years of research funding. CSTAR supports shorter-term research activities with colleges and universities through the NWS/Cooperative Program for Operational Meteorology, Education, and Training (COMET) Outreach Program. The NWS also funds specific applied research grants and cooperative agreements directly in support of hydrology and meteorology research needs.

TRAINING

NOAA's NWS provides training to its workforce to enhance the professional and scientific development of its staff in support of NOAA's NWS mission and strategic goals. Training deficiencies and requirements are identified and addressed via the National Strategic Training and Education Plan (NSTEP) process, described in NWS Instruction 20-102 and available at http://www.nws.noaa.gov/directives/020/pd02001002a.pdf.

Training is provided through a variety of in-residence courses and distance learning techniques. Hands-on, in-residence training can be acquired at any of the three NOAA's NWS professional training facilities. The NWS Training Center (NWSTC) in Kansas City, Missouri, provides technical, meteorological and hydrologic, and management/leadership training. The Warning Decision Training Branch (WDTB) in Norman, Oklahoma, conducts situational awareness and remote sensing training with modules that integrate data for improving the warning decision process. Finally, the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado, offers advanced meteorological and hydrometeorological education to ensure that NWS employees have access to the latest software and hardware to improve forecasting techniques. All three facilities also offer distance learning, Internet modules, teletraining, webcasts and CD-ROM based training. NWS employees have direct access to scientific and managerial training materials through the DoC/NOAA Learning Management System (LMS).

The NWSTC, in addition to providing scientific and technical training, is working to expand its leadership training and development skills through NOAA's NWS Leadership Academy. The goal of the Leadership Academy is to enable NWS and NOAA employees to become world-class leaders. The Academy is founded on a sequential and progressive approach designed to develop professional skills and capabilities to improve employee performance. From entry into the agency to senior career status, employees can take advantage of courses and processes that are part of a powerful management and leadership learning environment. Finally, NOAA's NWS is working to develop an organized curriculum to supply the necessary knowledge, skills, and abilities for all positions.

NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE

The National Environmental Satellite, Data, and Information Service (NESDIS), part of the National Oceanic and Atmospheric Administration (NOAA), manages the U.S. civil operational environmental satellite systems, as well as the three NOAA National Data Centers (NNDCs) that develop global, national, and regional databases to support meteorology, oceanography, geophysics, and the space environment. From these sources, NESDIS develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and the development and management of environmental resources.

NESDIS was established as a NOAA line office on December 1, 1982. The merger of the former National Environmental Satellite Service (NESS) and the Environmental Data and Information Service (EDIS) formed NESDIS.

NESDIS procures, launches, and operates two types of satellites to provide worldwide environmental data and information products and services to Federal agencies, state and local governments, and private users. These satellite types are the Polar-orbiting Operational Environmental Satellite (POES) and Geostationary Operational Environmental Satellites (GOES).

The POES satellites are circling the Earth in an almost north-south orbit, passing close to both poles. These orbits have an altitude between 830 km (morning orbit) and 870 km (afternoon orbit), and are sun synchronous. One satellite crosses the equator at 10:00 A.M. local time, the other at 2:00 P.M. local time. Operating as a pair, these satellites ensure that data for any region of the Earth are no more than six hours old. Each satellite orbits the Earth 14 times per day, collecting global data for atmospheric and surface measurements in support of short-term weather forecasting and long-term global climate change research. NOAA also manages the command, control, and communications function of the Department of Defense's

(DOD's) Defense Meteorological Satellite Program (DMSP) constellations.

Currently NESDIS is operating six polar orbiters. The newest series of POES satellites began with the launch of NOAA-15 in May 1998, followed by NOAA-16 on September 21, 2000, NOAA-17 on June 24, 2002, and finally NOAA-18 on May 20, 2005. NOAA-17 and NOAA-18 are classified as the primary operational satellites. The NOAA-12, NOAA-14, NOAA-15, and NOAA-16 satellites continue to transmit data as stand-by satellites. NOAA-17 serves as the primary morning satellite and NOAA-18 the primary afternoon satellite.

An agreement with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) gives EUMETSAT responsibility for the morning segment of NOAA's polar environmental mission (circa 9:30 A.M. LST), with U.S.-provided payload instruments and sensors, beginning in 2006. Upon inception of this operational arrangement, NOAA will operate the afternoon mission while EUMETSAT will support the morning mission. Under this joint mission, upgraded instruments will be flown that will result in improvements for the user community. For example, the HIRS instrument will be upgraded resulting in improved atmospheric sounding information. AVHRR global one-kilometer data will be available enhancing the usefulness of this data for fire detection, CoastWatch, and any other applications that require higher resolution. It also provides the opportunity to use new sensor data from EUMETSAT instruments, in preparation for future NPOESS support

The National Polar-orbiting Operational Environmental Satellite System (NPOESS), the next generation of polar-orbiting satellites, will provide standard meteorological, oceanographic, environmental, and climatic information as well as space environmental remote sensing information. NPOESS will also continue to provide surface data collection and search and rescue capability. The NPOESS IPO, in consultation with the POES and DMSP program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued non-interrupted data services. The first NPOESS launch is planned for 2013.

NESDIS is also responsible for operating two geostationary satellites, referred to as GOES East and GOES West, plus an on-orbit spare satellite. Each satellite views nearly one third of the Earth's surface. The GOES-12 (East) satellite is positioned at 75

degrees W longitude and the equator and monitors North and South America and most of the Atlantic Ocean. GOES-11 (West) is positioned at 135 degrees W longitude at the equator and monitors North America and the Pacific Ocean basin. These two satellites operate together to provide continuous monitoring necessary for effective and extensive weather forecasting, prediction, and environmental monitoring. GOES East and West circle the Earth in a geosynchronous orbit, which means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. This allows them to continuously view one part of the Earth's surface. The geosynchronous orbit is about 35,800 km (22,300 miles) above the Earth's equator.

On May 24, 2006, GOES-13 was launched. This spacecraft is the first spacecraft of the GOES N-P series. This new series improves NOAA's coverage during spacecraft eclipse season. After checkout of the satellite, GOES-13 will be available as a replacement for GOES East or West in the event of a failure. With the transition of GOES-11 to GOES West, GOES-10 will be repositioned to support South America as part of the Global Earth Observation System of Systems (GEOSS).

ENVIRONMENTAL SATELLITE SERVICES

OFFICE OF SATELLITE OPERATIONS

The Office of Satellite Operations (OSO) directs the operation of NOAA's environmental satellites and the acquisition of remotely sensed environmental data. It manages the Satellite Operations Control Center (SOCC) in Maryland, and two Command and Data Acquisition (CDA) stations (Fairbanks, Alaska, and Wallops, Virginia), which command, control, track, and acquire data from environmental satellites. The status of NOAA's satellites can be found on OSO's website (http://www.oso.noaa.gov/).

OSO also performs the command, control, and communications function of the Department of Defense's (DOD's) Defense Meteorological Satellite Program (DMSP) constellation. The mission of DMSP is to provide meteorological and special sensor data to users in support of worldwide DOD missions. DMSP is now operated from the SOCC at Suitland, Maryland. SOCC is the primary center for normal operations, mission planning, engineering, launch and early orbit support, and anomaly resolution.

OFFICE OF SATELLITE DATA PROCESSING AND DISTRIBUTION

The Office of Satellite Data Processing and Distribution (OSDPD) is responsible for the operations of NESDIS central ground data processing facilities. It processes and distributes data from NOAA and non-NOAA environmental satellites and generates automated and interpretive products for various government agencies, private industry, and educational institutions. Key customers include NOAA's National Weather Service (NWS), DOD, Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), worldwide Meteorological Watch Offices, Environmental Protection Agency (EPA), and state environmental protection agencies, foreign meteorological agencies, U.S. airlines, universities, and private sector companies. OSDPD exploits data from NOAA polar and geostationary environmental satellites, foreign (European, Japanese, and Indian) operational satellites, as well as domestic and foreign research satellites. The latter includes NASA's Tropical Rainfall Measuring Mission (TRMM), QuikSCAT, Earth Observing System satellites (including Aqua, Terra, and Aura missions), Japan's ADEOS-II, and DOD's WindSAT mission. OSDPD products are used in real-time in the production of forecasts and warnings of severe environmental events such as tornados, thunderstorms, flash floods, and hurricanes. Some OSDPD products, such as calibrated radiances from polar-orbiting sounders, vertical temperature and moisture profiles, cloud tracked wind speed and direction, and snow cover, are routinely integrated into numerical weather prediction forecast models on a global scale. These products often provide key model input parameters where routine in-situ measurements are not available.

OSDPD satellite products are distributed to a diverse user community for a broad range of environmental applications. The operational satellite data distribution networks provide user access to real-time or near, real-time environmental data and information. Quality assurance procedures are used to systematically evaluate and characterize the satellite products and services. This applies to both the fully automated products such as remapped GOES channel imagery and geophysical parameters (e.g., vertical wind profiles, bulk moisture and atmospheric stability indices, etc.) and POES-derived parameters (e.g., channel brightness temperatures, precipitation estimates, vegetation indices, sea surface temperature, temperature and moisture profiles, etc.), as well as to the value-added interpretive or analyzed products used to support disaster mitigation and warning services for various Federal agencies and the international community. The latter category includes products such as tropical storm position and intensity, fire locations and associated smoke extent, quantitative precipitation estimates for flash flood warnings, and volcanic ash plume extent and height. OSDPD works closely with its partners in the customer-supplier chain to ensure the most effective and timely implementa-

tion of its satellite data products and services. Working with NESDIS research organizations, such as the Office of Research and Applications (STAR) on the supplier side, and with government (primarily NWS), educational, and other organizations on the customer side, new and enhanced product generation algorithms are tested, evaluated, and implemented when deemed sufficiently validated and operationally useful. In partnership with other agencies and internal NESDIS organizations, new technologies are investigated and periodically deployed to satisfy emerging user requirements.

OSDPD distributes these environmental satellite products to NWS Advanced Weather Interactive Processing System (AWIPS), National Centers for Environmental Prediction (NCEP), Weather Forecast Offices (WFOs), and other Federal, state, and private sector organizations. This is done through dedicated satellite processing and server configurations or through the NOAAPORT satellite point-to-multi-point broadcast facility. The satellite data and products transmitted via NOAAPORT include remapped imagery, satellite precipitation estimates, high-density wind direction and speed projections at various atmospheric levels, GOES satellite imagery, and volcanic ash advisory messages. Over 100 universities receive satellite data and products supplied via NOAAPORT. NOAAPORT also delivers GOES and POES products in near, real-time to the AWIPS.

AWIPS is the NWS display and analysis workstation used in NWS national centers and field sites to integrate and display satellite data, model output, in-situ observations, and radar and wind profiles used in the production of hydro-meteorological analyses and forecasts. In addition, OSDPD serves NCEP as a backup for NOAA GOES data via the Man Computer Interactive Data Access System (McIDAS) and as a primary source to NCEP of NOAA POES and non-NOAA geostationary satellite data.

OSDPD also uses various websites to disseminate satellite data and products. For example, one site (http://www.ssd.noaa.gov) provides information and products on a multitude of OSDPD operational product areas including: worldwide tropical cyclone analyses, volcanic ash analyses, heavy precipitation analyses, snow/ice cover, and smoke and fire analyses. High quality imagery and derived products are extremely popular during hurricane season. Another OSDPD website (http://www.osei.noaa.gov) provides satellite imagery of significant environmental events such as oil spills, icebergs, hurricanes, and fires. Satellite data in digital scientific format are also available at ftp://gp16.ssd.nesdis.noaa.gov/, and several data sets are made available in Geographic Information System (GIS) format through http://www.gis.ssd.nesdis.noaa.gov/. A variety of geophysical products derived from both NOAA and non-NOAA polar orbiting platforms can be found at http://www.osdpd.noaa.gov/PSB/PSB.html.

OSDPD continues to support COSPAS-SARSAT, the international search and rescue program through provision of satellites, ground stations, and alert data distribution services. In 2005, COSPAS-SARSAT contributed to the rescue of 222 people in the U.S., bringing the worldwide total to over 18,500 rescues since its inception in 1982. In the COSPAS-SARSAT program, Russia, the U.S., India, France, and Canada provide the space segment, and 31 other countries provide ground systems to relay distress alerts and participate in the management of the program. NESDIS operates and maintains the U.S. SARSAT Mission Control Center and 12 Local User Terminals as ground stations.

The Local User Terminals receive 121.5/243/406 MHz emergency beacon signals directly from the satellites and process the information to provide the location of distress transmissions. COSPAS-SARSAT will terminate satellite processing of 121.5/243 MHz signals beginning February 1, 2009. This decision was made in response to guidance from the International Civil Aviation Organization and the International Maritime Organization due to problems in this frequency band that cause poor accuracy and numerous false alerts, adversely impacting the effectiveness of lifesaving services. These two specialized agencies of the United Nations are respectively responsible for international aviation and maritime search and rescue standards. The use of new emergency beacons that can use the Global Positioning System (GPS) to provide an accurate position continues to increase. NESDIS, working with its partners in the U.S. Air Force, U.S. Coast Guard, and NASA, is developing plans to augment the COSPAS-SARSAT System

with search and rescue instruments on future Global Positioning System (GPS) Block III satellites.

NATIONAL ICE CENTER

The U.S. National Ice Center (NIC), under the sponsorship of the U.S. Navy, NOAA, and the U.S. Coast Guard, is tasked with providing the highest quality operational global, regional, and tactical scale sea ice analyses and forecasts tailored to meet the requirements of U.S. national interests. NIC ice products are produced in a digital geospatial intelligence environment using data from polar orbiting satellites, ship/shore station reports, drifting buoys, meteorological guidance products, ice model predictions, and data from other government partners including foreign ice services. Primary remotely sensed data sources used for global and regional ice mapping include visible and infrared imagery from the POES imager, AVHRR (1.1 km spatial resolution), and the DMSP Operational Linescan System (0.55 km spatial resolution). NIC also uses passive microwave sensor data from the Special Sensor Microwave Imager (SSM/I), the Advanced Microwave Scanning Radiometer (AMSR-E), and WindSat processed using CAL/VAL, NASA Team 2, and Bootstrap sea ice concentration algorithms. These algorithms produce 25 km gridded mosaic ice maps that are instrumental in the production of NIC weekly composite Arctic/Antarctic ice maps, particularly over areas of extensive cloud cover. Higher resolution ice analysis products, used to ensure the safety of navigation and protect life and property at sea, are available from active microwave sensors such as the SeaWinds scatterometer aboard QuikSCAT and Synthetic Aperture Radar (SAR) instruments aboard the Canadian RADARSAT-1 and the European Envisat satellites. When available, SAR data are the source of choice for sea ice analysis. Most of the SAR imagery available to NIC is RADARSAT-1 ScanSAR wide mode that provides a 500 km wide swath with 100 m spatial resolution. These images are processed at four different ground stations and transferred to NIC via dedicated communication lines or via the Internet within six hours of acquisition. The NIC Science Team, supported by the NESDIS Center for Satellite Applications and Research (STAR), assists in the transition of pertinent scientific research to operations. This includes the transition of new real-time passive and active microwave sea ice products to the NIC operations floor, conducting an evaluation of current sea ice algorithms, and the use of satellite and in-situ data for initializing and evaluating the Polar Ice Prediction System (PIPS) version 3.0.

Routine NIC ice guidance products include regional-scale ice maps, annotated satellite imagery, short and long-term ice forecasts, and legacy ice information and ice climatology. Specialized support services include specific regional support, ship route recommendations, pre-sail ship briefings, aerial ice reconnaissance, and ship rider support. Specific sea ice features analyzed include ice edge position, ice concentration, ice thickness, form or floe size, ice motion, areas of compression and heavy surface deformation, and the location/orientation of open water or thin ice-covered leads.

Ice products are disseminated via the Internet (www.natice.noaa.gov) as simple electronic charts in Joint Photographic Experts Group (JPEG format), GeoTiff, and other GIS-compatible formats consistent with the World Meteorological Organization (WMO) digital standard for Sea Ice in GRIDDED (SIGRID-3) format. The date and time of data acquisition as well as the percentage of each data type used in all ice analyses are documented in a meta-data narrative.

Another NIC responsibility is oversight of the U.S. Interagency Arctic Buoy Program (USIABP). The USIABP was established in 1992, to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields. Data are used in real-time for operational weather and ice forecasting and for research in the Global Climate Change Program. The USIABP is a collaborative program that draws operating funds and services from the collective contributions of government agencies and/or programs. These organizations include: the Naval Oceanographic Office, Office of Naval Research (ONR), NASA, National Science Foundation (NSF), and NESDIS, Office of Oceanic and Atmospheric Research (OAR), and the Office of Global Programs (OGP).

CENTER FOR SATELLITE APPLICATIONS AND RESEARCH (STAR)

STAR is the science arm of NESDIS. The mission of STAR is to transfer satellite observations of the land, atmosphere, ocean, and climate from scientific research and development into routine operations, and offer state-of-the-art data, products and services to decision-makers. STAR is an operations-driven research and development center, tuned to the needs of the nation's users of satellite data products. STAR conducts diverse research on satellite remote sensing, including the study of atmospheric, oceanic, and land processes. STAR participates in the life cycle of all operational NOAA satellites-from defining the initial requirements for a satellite mission, through calibration and application of the data after the satellite is in orbit, to development of products from the data, to final archiving and even reprocessing of data. STAR also works with data from non-NOAA satellites as

well, for research, to transfer capabilities to NOAA, and to obtain even more observations of the Earth than what is available from NOAA satellites.

STAR is a leader in planning future satellite observing systems to enhance the nation's ability to remotely monitor the environment. STAR also calibrates the Earth-observing instruments of all NOAA satellites to provide reliable measurements. STAR investigates how to develop satellite data sets that can be used in the following ways:

- Assess the current conditions on the Earth in a timely manner,
- Predict changes in the current conditions, and
- Study long-term trends in the environment.

NOAA's mission includes providing information, forecasts, advisories, and warnings on the earth's atmosphere, land, and ocean. STAR develops the techniques to obtain the necessary information from satellite data. STAR also supports the NOAA mission by providing scientific services to the users of NOAA satellites:

- Planning new satellites and sensors that monitor the environment,
- Collecting and processing data from environmental satellites,
- Building quality and reliability into NOAA satellite data, and
- Providing satellite products that NOAA can use to accomplish its mission.

STAR will create new products for monitoring atmospheric, oceanic, and environmental hazards; enhance NOAA's infrastructure for remote sensing; reduce the risk of launching new, untested, and very expensive satellites and sensors; expand its support to users (for example, expanding the NOAA CoastWatch Program into a global OceanWatch); and train users of STAR products and applications.

THE JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA)

The JCSDA is a geographically distributed center operated as a partnership between NOAA, NASA, the U.S. Navy, and the U.S. Air Force. This cooperative arrangement allows NOAA, NASA, and DOD to take advantage of their combined science and technology resources in order to accelerate and optimize the use of existing and new satellite data for numerical weather prediction (NWP).

The JCSDA provides a focal point for cooperative research and development of common modeling and data assimilation infrastructure among its partners. As a result of its collaborative nature, the JCSDA will enable NOAA to improve NWP and climate prediction through the optimal use of data from existing satellites and to prepare for a large volume of new data from advanced satellite instruments, such as those on NPOESS, that will be launched during the next five to six years. These efforts will also help guide the selection and specification of future satellite instruments to ensure that the most effective observing system possible is created.

The JCSDA is tasked with developing new and powerful techniques to assimilate data into NWP and ocean, climate, and air quality analyses and models. This center is also tasked with reducing the time elapsed from satellite launch to operational data use from two years to one year. JCSDA activities directly support the missions of NASA, NOAA, and the DOD as well as those of organizations who contribute to or rely on NOAA's environmental assessment, prediction, and stewardship missions. In addition, through its partnership and coordination with DOD and other agencies, the JCSDA will enhance efforts to facilitate the transition from research into operations. Current projects focus on speeding available satellite data into operations and developing tools to support future assimilation projects. Six scientific priorities are being emphasized toward these ends:

- Development of a community-based radiative transfer model (CRTM): In the next few years, the accuracy and capability of the JCSDA CRTM will be significantly improved by including additional physical processes (e.g., atmospheric scattering), more efficient numerical techniques, and better surface emissivity models to allow more satellite data which is affected by surface to be properly assimilated.
- Development of data thinning and configuration technology and methodology: This allows faster and efficient delivery of advanced satellite data to major NWP centers globally.
- Advanced techniques to assimilate satellite data in cloudy and precipitation regions: Improving radiative transfer models and NWP cloud prediction schemes will significantly increase the fraction of satellite data being ingested into the assimilation systems and increase their impact.
- Improvement of the use of satellite land products in NWP models: For example, green vegetation fraction, snow cover, snow pack parameters, surface albedo, land, and sea surface temperature.
- Improvement of the use of satellite data in ocean data assimilation: This provides assimilated ocean data sets to

the community for research purposes and providing access to and support of an operational ocean data assimilation system.

• Assimilate satellite derived aerosol, ozone, and trace gas product: This will improve forecasts of visibility and health index with state-of-the-art air quality forecast models including chemical and biological process.

The JCSDA has additional long-term strategic goals. One is to accelerate the transfer of data assimilation research into operations by fostering common data assimilation code components, including techniques for specifying observation errors, background error co-variances, and data selection and reduction. Another is to foster development of a workforce capable of meeting the data assimilation challenges of future.

The JCSDA approach is bearing fruit. Recent accomplishments include:

• Improved radiative transfer techniques:

• CRTM was implemented operationally in the Global Data Assimilation System (GDAS).

• Improved microwave surface emissivity models leads to more AMSU-A data used over land, snow, ice.

• Vetted CRTM components are made available to partners and stakeholders via internet.

• Improved uses of current satellite data:

• More AMSU-A data are used over land, snow, and sea ice due to an improved surface emissivity model.

• Advanced data selection and assimilation techniques for infrared sounders increase use of AIRS data.

• NOAA-18 AMSU data is used operationally in NCEP GDAS.

• OMI Ozone data from TERRA satellite result in improved global ozone analysis.

• AIRS data used to predict NWP effectiveness of proposed designs for a future GOES-R sounder.

• More new satellite data tested for use in NCEP operational GDAS and forecast models:

• Techniques to assimilate GPS Radio Occultation data is developed, has been tested, and will improve NWP.

• WindSat ocean surface wind data was tested in the Global Forecast System with positive impact.

• JASON sea-surface altimetry data was tested in the Global Ocean Data Assimilation System.

POLAR SATELLITE PROGRAM

The primary mission of the Polar-orbiting Operational Environmental Satellite (POES) System is to provide daily global observations of weather patterns and environmental measurements of the Earth's atmosphere, its surface and cloud cover, and the proton and electron flux at satellite altitude. Since the beginning of the POES program, environmental data and products acquired by its satellites have been provided to users around the globe. These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the two primary operational spacecraft are NOAA-17 and NOAA-18.

NOAA polar satellites carry instruments that provide atmospheric temperature and moisture profiles. They also provide multi-channel images and carry a data collection and platform location system and a Search and Rescue Satellite-Aided Tracking (SARSAT) subsystem. The SARSAT subsystem is used to detect and locate distress alerts from maritime, aviation, and land-based users of emergency beacons operating at 121.5 or 243 or 406 MHz. In addition to taking thermal images of the Earth's surface and atmosphere, the NOAA polar-orbiting satellites carry sounder instruments to provide vertical profiles of atmospheric temperature and moisture.

POES satellites carry four primary instrument systems: the Advanced Very High Resolution Radiometer (AVHRR); the TIROS Operational Vertical Sounder (TOVS); the Space Environment Monitor (SEM); and the Solar Backscatter Ultra-Violet Instrument (SBUV/2). AVHRR provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. The AVHRR/3 series of instruments, which began with NOAA-15, measures in six spectral channels (0.63, 0.86, 1.6, 3.75, 10.8 and 12 μm) with a nominal spatial resolution of 1.1 km and global resolution of roughly 4 km. Though the AVHRR/3 measures six channels, only five are transmitted in the data stream at any one time; the 1.6 and 3.75 m channels are time shared. The AVHRR/3 provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, fire detection, and snow and ice mapping. TOVS is comprised of the High-resolution Infrared Radiometer Sounder (HIRS) and the Advanced Microwave Sounding Unit (AMSU).

The HIRS/3 is a discrete-stepping, line scan instrument designed to measure scene radiance in 20 spectral bands to permit the calculation of the vertical temperature profile from Earth's surface to about 40 km. Multi-spectral data from one visible channel (0.69μm), seven shortwave channels (3.7 to 4.6μm), and twelve long wave channels (6.5 to 15μm) are obtained from a single telescope and rotating filter wheel containing twenty individual filters. An elliptical scan mirror provides cross-track scanning of 56 increments of 1.8μm. The mirror steps rapidly (<35 msec), then holds at each position while the 20 filter segments are sampled. This action takes place

every 100 msec. The instantaneous field of vision (FOV) for each channel is approximately 1.4 μm in the visible and shortwave IR and 1.3 μm in the long wave IR band that, from an altitude of 833 km, encompasses an area of 20.3 km and 18.9 km in diameter, respectively, at nadir on the Earth.

Each AMSU-A instrument is composed of two separate units: (1) AMSU-A2 with two channels at 23.8 and 31.4 GHz and (2) AMSU-A1 with twelve channels in the range of 50.3 to 57.3 GHz and one channel at 89.0 GHz. The AMSU-B has five channels with frequencies centered on 89, 150, 183±1, 183±3, and 183±7 GHz, respectively. AMSU-B, provided by the United Kingdom Meteorological Office, produces soundings of humidity from the surface to 200 millibars (mb). AMSU-A has a nominal FOV of 3.3 degrees (48 km on surface at nadir) and AMSU-B a field of view of 1.1 degrees (16 km on surface at nadir). AMSU-A (AMSU-B) samples 30 degrees (90 degrees) Earth views, covering ±48.95 degrees from the subsatellite point. In addition, the specialized 89 GHz channel, with the capability to see through high and mid-level clouds to low level precipitation producing clouds, is used to determine the position and structure of tropical cyclones on a global scale. The AMSU-A1 uses two antenna systems, providing observations in the twelve oxygen band channels (3-14) for retrieving the atmospheric temperature profile from the Earth's surface to about 42 km, or from 1000 to 2 mb. The remaining three channels (1 and 2 from A2 and 15 from A1) aid the retrieval of temperature soundings by correction of surface emissivity, atmospheric liquid water, and total precipitable water. These window channels also provide information on precipitation, sea ice, and snow coverage.

The Microwave Humidity Sounder (MHS) is a new instrument for the NOAA satellites. It is a five-channel microwave instrument intended primarily to measure profiles of atmospheric humidity. It is also sensitive to liquid water in clouds and so measures cloud liquid water content. Additionally, it provides qualitative estimates of the precipitation rate.

The SEM measures solar proton flux, alpha particle and electron flux density, and energy spectrum and total particulate energy distribution at spacecraft altitudes. The two sensors included within this instrument are the Total Energy Detector (TED) and the Medium Energy Proton and Electron Detector (MEPED), in addition to a common data processing unit. This instrument augments the measurements made by NOAA's geostationary satellites.

The NOAA-16, NOAA-17, and NOAA-18 POES carry the Solar Backscatter Ultraviolet Instrument (SBUV/2). The SBUV/2 instrument is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth. Ozone evaluation, calibration, and validation activities took place for the new Solar Backscatter Ultraviolet Instrument (SBUV/2) with the launch and successful checkout of NOAA-17 & 18. A new ozone profile retrieval algorithm (Version 8) is under development at NASA. As soon as it becomes available, NOAA will begin to incorporate it in its SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-14, NOAA-16, NOAA-17, NOAA-18, and with the TOVS instruments on NOAA-14, NOAA-15, NOAA-16, NOAA-17, and NOAA-18. Experimental ozone products at high temporal resolution are also being produced from the GOES-8 sounder channels. Monitoring is limited to North America. Preliminary results show the GOES total ozone values are comparable to amounts from the Total Ozone Mapping Spectrometer and ground-based measurements.

The ground system required to receive large volumes of digital data from NOAA satellites consists of two major subsystems: the Polar Acquisition and Control Subsystem (PACS) and the Central Environmental Satellite Computer System (CEMSCS). The PACS includes the Wallops, Virginia, and Fairbanks, Alaska, Command and Data Acquisition (CDA) stations and the SOCC at Suitland, Maryland. All the CEMSCS components are in the NOAA facility at Suitland. PACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the CEMSCS processing and data handling facility. The delivery of NOAA system data from the CDA to Suitland is accomplished by using the General Electric American Communications, Inc. commercial satellite communications network. This system, which includes Earth stations at Suitland, Wallops, and Fairbanks, delivers the data to SOCC. These data are immediately passed to the CEMSCS for processing. The CEMSCS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location, calibration, and quality control parameters. The data processed by the CEMSCS are used for environmental products and operational weather predictions that are disseminated to users throughout the world.

The Argos Data Collection (and location) Service (DCS) operates on the NOAA Polar-orbiting Operational Environmental Satellite (POES) constellation and was established through a Memorandum of Understanding (MOU) with France in 1974, and

renewed in 1986. The lead agencies for this international cooperative agreement are NOAA and the Centre National d'Etudes Spatiales (CNES) for France. CNES provides for the development and delivery of the Argos DCS instrument. NOAA provides spacecraft integration/launch services, downloads stored mission data via NOAA Command Data Acquisition facilities, and provides pre-processed data delivery. Data post-processing and delivery to customers is the responsibility of CNES, which through a subsidiary maintains distribution centers located in Toulouse, France, and Largo, Maryland.

The Argos DCS is a space-based, data telemetry system that provides a global means to locate and collect environmental data from fixed and moving, low-power transmitters; i.e., polar ice buoys, ocean floats, birds, mammals, etc., in near, real-time (15 minutes to 3 hours). The Argos DCS transmits data for operational and research related environmental applications, e.g., meteorology, oceanography, and protection of the environment, with the majority of users being government/non-profit agencies and researchers. Argos DCS customers are engaged in over 1,000 programs operating approximately 15,000 data collection platforms in 72 countries.

The Argos DCS program will incorporate Argos instruments on other international satellite platforms as opportunities permit, such as the European Organization for Exploration of Meteorological Satellites (EUMETSAT) to fly Argos DCS on the METOP satellite series (2006-2020). Future instrument developments include the incorporation of a downlink message capability, scheduled to fly on the Metop-A, NOAA-N' and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) constellation (2013-2026). This new capability, in response to customer requirements, will provide the opportunity for new and novel uses of the Argos DCS and allow the user to communicate with deployed platforms in the field.

GEOSTATIONARY SATELLITE PROGRAM

Two operational geostationary satellites, GOES-12 (75 degrees W) and GOES-11 (135 degrees W), provide coverage of virtually the entire western hemisphere for operational environmental sensing of the Earth. GOES-13, formerly GOES-N, was launched on May 24, 2006. After a successful checkout, GOES-13 will be stored in orbit at 105 degrees W. GOES-10 (formerly GOES West) was replaced by GOES-11 and, at the conclusion of GOES-13 checkout, will transition to serve South America in support of NOAA, the Comisión Nacional de Activades Espaciales, and the World Meteorological Organization (WMO) agreement. The shift of GOES-10 will help protect lives and property in North, Central, and South America by significantly improving satellite detection of severe storms, floods, drought, landslides, volcanic ash clouds, and wildfires. The shift will further strengthen the WMO's World Weather Watch Global Observing System. It will allow for improved prediction, response and follow-up and expanded understanding of how our Earth system works. The projected launch schedule and associated instruments for geostationary satellites are shown in Table 3.1. It should be noted that current plans as of mid 2006 call for GOES-13 to be placed in storage once checkout is completed late 2006. GOES-11 replaced GOES-10 in the west in June 2006 and GOES-12 to remain in the east. GOES-10 will be moved to 60 degrees West in late 2006, to support the Earth Observation Partnership of Americas (EOPA) program which is part of the GEO program.

The GOES satellites host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the 3.9 μm and 13.35 μm wavelengths. Beginning with GOES-12, the 12.0 μm channel was replaced with a 13.35 μm channel, with the goal of achieving more accurate cloud height assignments for mid- and upper-level atmospheric satellite wind-velocity estimates. This trade-off notably impacts the sea-surface temperature retrievals by eliminating the capability for daytime split-window retrievals, increasing the rms error by about 0.5 C. Also, the spatial resolution of the water vapor channel is improved to 4 km from 8 km.

GOES satellites transmit all five spectral bands simultaneously, providing the user community with continuous views of atmospheric measurements in various wavelengths, each with its own atmospheric, land, and ocean application. GOES spacecraft were designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled. For example, the full-Earth disk is normally scanned once every 3 hours and requires about 30 minutes to complete the entire scan. Depending on requirements to monitor environmental hazards on the Earth's surface or in the atmosphere, 30-minute periods in between the full-disk scans may be scheduled as a mixture of 15-minute intervals (routine operations) or 7.5-minute interval (severe storm operations) rapid scans over the contiguous US. To further support mesoscale and microscale analyses, 1000 km x 1000 km areas can also be scanned at 1-minute intervals, to capture rapidly developing and dynamic environmental phenomena..

For GOES 11, the five channels and respective resolutions are as follows:

- Channel 1 (Visible, .55 m to .75 m) 1 km.
- Channel 2 (Infrared, 3.8 m to 4.0 m) 4 km.
- Channel 3 (Water Vapor, 6.5 m to 7.0 m) 8 km.

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA-N	CY 2005
METOP-2	CY 2010
NPP	CY 2010
NOAA-N'	CY 2007
NPOESS-C1	CY 2013
METOP-1	CY 2006
NPOESS-C2	CY 2016
NPOESS-C3	CY 2018
METOP-3	CY 2015
NPOESS-C4	CY 2020

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES N	CY 2006
GOES O	CY 2008
GOES P	CY 2009
GOES Q	Cancelled
GOES R	CY 2012
GOES S	CY 2014
MTSAT-1R	CY 2005

*Launch date depends on performance of prior spacecraft and is subject to change.

NOAA Instruments for NOAA Polar-Orbiter and METOP Series

AVHRR - Advanced Very High Resolution Radiometer
SEM - Space Environment Monitor
SBUV - Solar Backscatter Ultraviolet Instrument (NOAA PM mission only)
HIRS - High Resolution Infrared Sounder
DCS ARGOS - Data Collection System
AMSU-A - Advanced Microwave Sounding Unit-A
AMSU-B - Advanced Microwave Sounding Unit-B
SARP - Search and Rescue Processor
SARR - Search and Rescue Repeater
MHS - Microwave Humidity Sounder (NOAA-N/N' and METOP)

Instruments for NPOESS Series

VIIRS - Visible/Infrared Imager/Radiometer Suite
Microwave Imager/Sounder (to be determined by new competition for C2)
CrIS - Cross-track Infrared Sounder
ATMS - Advanced Technology Microwave Sounder
OMPS - Ozone Mapper/Profiler Suite -Nadir
A/DCS - Advanced Data Collection System
SARSAT - Search and Rescue Satellite-Aided Tracking System
CERES - Cloud and Earth Radiant Energy System (to be flown on C1 only)
SEM - Space Environment Monitor

Instruments for GOES-R+ Series

Advanced baseline Imager (ABI)
Hyperspectral Environmental Suite (HES)
Solar Instrument Suite (SEI)
Space Environment In-Situ Suite (SEISS)
Geostationary Lightning Mapper (GLM)

EUMETSAT Unique Instruments for METOP Series Satellites

ASCAT - Advanced Scatterometer
GOME - Global Ozone Monitoring Experiment
GRAS - GPS Receiver for Atmospheric Sounding
IASI - Infrared Atmospheric Sounding Interferometer

• Channel 4 (Infrared, 10.2 m to 11.2 m) 4 km.

• Channel 5 (Infrared, 11.5 m to 12.5 m) 4 km.

For GOES-12/13, the five channels and respective resolutions are as follows:

• Channel 1 (Visible, .52 m to .71 m) 1 km.

• Channel 2 (Infrared, 3.73 m to 4.07 m) 4 km.

• Channel 3 (Infrared, 13.0 m to 13.7 m) 8 km (4 km starting with GOES O-P).

• Channel 4 (Infrared, 10.2 m to 11.2 m) 4 km.

• Channel 5 (Water Vapor, 5.8 m to 7.3 m) 4 km.

The GOES sounder instruments, consisting of 19 spectral channels, are used for measurements of atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. Products derived from the sounder include precipitable water and lifted index - a measurement of atmospheric stability. Comparable to the imager, the sounder is capable of providing various scan coverage, such as full Earth imagery, sectored imagery, and local imagery. In routine operations, GOES-12 and GOES-11 provide hourly sounding coverage.

The GOES Space Environment Monitor (SEM) collects data for warnings of solar activity. This block of instruments is more extensive than on POES. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors, and three component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to support operational NOAA and DOD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center and provided to retrospective users on line via Internet and on a variety of computer media.

Starting with GOES-12, a Solar X-Ray Instrument (SXI) is being flown that provides near, real-time X-ray images of the sun for ionospheric changes that affect radio communications and mangetospheric variations that induce currents in electrical power grids and long distance pipelines. Also, these conditions can cause navigational errors in magnetic guidance systems, introduce changes in spacecraft charging, produce high energy particles that can cause single event upsets in satellite circuitry, and expose astronauts to increased radiation. The SXI will observe solar flares, solar active regions, and coronal structures. Images from the SXI will be used by NOAA and U.S. Air Force forecasters to monitor solar conditions that affect space weather conditions, including the dynamic environment of energetic particles, solar wind streams, and coronal mass ejections emanating from the sun.

GOES also carries a Data Collection System (DCS), which is used to collect and relay environmental data observed by a variety of remotely located platforms, such as river and tide gauges, seismometers, buoys, ships, and automatic weather stations. In support of NOAA missions, GOES DCS data are used in weather forecasts and warnings, reservoir control, and flood monitoring. While the GOES DCS is a critical element for national and international meteorological and hydrological programs, the NWS NEXRAD program relies on the DCS data as a vital input for calibration and validation. Tsunami watches and warnings for the Pacific Ocean are prepared using the Data Collection Platform data transmitted via GOES DCS. The GOES DCS program touches all aspects of our lives in supporting water quality, air pollution, and global environmental monitoring.

The GOES Search and Rescue Satellite Aided Tracking (SARSAT) System is capable of providing an immediate distress alert, unlike the POES satellite SARSAT transponders which must come within line of site of a Local User Terminal, in order to relay the distress beacon back to the U.S. SARSAT Mission Control Center (USMCC). Newer state of the art COSPAS-SARSAT distress beacons, utilizing the Global Positioning System (GPS), now have the capability to provide location information in the distress message relayed by GOES to the USMCC.

NESDIS continues to improve user access to its operational satellite products and services using new communications technologies including the Internet. One important on-line access system, managed and operated by OSD is the Comprehensive Large-Array Data Stewardship System (CLASS). The CLASS (www.CLASS.noaa.gov) provides satellite data access, display, and electronic transfer. Available data types include AVHRR, ATOVS, DMSP (special sensor), and RADARSAT (authorized subscription users). While developed as an independent system, the Satellite Active Archive (SAA) serves as NOAA's initial interoperable interface to NASA's Earth Observing System Data and Information System (EOSDIS). After the phase out of the GOES TAP system in 1998, many users now rely on GOES sectorized images, mapped to standard AWIPS grids, available in near, real-time at *www.goes.noaa.gov.*

Near-real-time images and interpretive analyses of tropical storms and hurricanes worldwide, ash from volcanic eruptions within the western hemisphere, heavy precipitation in the U.S. which cause flash flooding or blizzards, wild fires and smoke within the US, and northern hemisphere snow boundaries are located at *www.ssd.noaa.gov*. Specially enhanced and annotated imagery and image loops of environmental events, such as flooding, hurricanes and other severe storms, volcanic eruptions,

fires, and dust storms are available from *www.osei.noaa.gov*. This web site was set up for use by the news media and general public, and to provide once or twice per day satellite views of an environmental event for Federal, state, and international governments and agencies. Also supporting the media, scientific organizations, and Federal and state agencies is a specially designed web site featuring visualizations of satellite data, found at www.nnvl.noaa.gov/.

INTERNATIONAL AND INTERAGENCY SUPPORT FOR DISASTER MANAGEMENT

International Charter

NOAA is a member of the International Charter for Space and Major Disasters. NOAA is represented on the Executive Secretariat and the Board of the International Charter and periodically serves as the lead agency providing secretariat services, policy leadership, and Charter activities coordination.

The International Charter aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through authorized users. Each member agency (the European Space Agency, France's Centre National d'Etudes Spatiales, the Indian Space Research Organisation (ISRO), NOAA, Argentina's Comisión Nacional de Actividades Espaciales, the Japan Aerospace Exploration Agency (JAXA), USGS, and DMC International Imaging) has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property. An authorized user can call a single number to request the mobilization of the space and associated ground resources of the six space agencies to obtain data and information on a disaster occurrence.

U.S. Interagency Collaboration

NOAA is a member of the U.S. Subcommittee on Disaster Reduction (SDR), which provides a unique Federal forum for information sharing; development of collaborative opportunities; formulation of science and technology based guidance for policy makers; and dialogue with the U.S. policy community to advance informed strategies for managing disaster risks. Last year, the SDR, through the President's National Science and Technology Council, released a report entitled "*Grand Challenges for Disaster Reduction*." This report identifies six grand challenges for disaster reduction and provides a framework for prioritizing related Federal investments in science and technology. In December 2005, the SDR released a joint report with the U.S. Group on Earth Observations, "*Tsunami Risk Reduction for the U.S.: A Framework for Action*." The plan places the President's initiative to improve domestic warning capabilities in the context of a broad national tsunami risk reduction effort and U.S. participation in international efforts to reduce tsunami risk worldwide.

SUPPORTING RESEARCH PROGRAMS

Recent advances in numerical weather prediction (NWP) models, both at NOAA's NCEP and other major International NWP Centers, require higher quality satellite-derived winds, particularly over the traditionally data void oceanic regions of the globe. The NESDIS GOES East and West wind processing suites are totally automated and use a series of geostationary satellite images to derive wind estimates. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite water vapor and infrared brightness temperature data to assign heights to these derived wind estimates. The automated quality control of image registration is also an important component of the NESDIS GOES-East and West winds processing suite.

Approximately 20,000 cloud-drift and water vapor motion wind vectors are derived from both satellites for each cycle and distributed to EMC and to the Global Telecommunications System (GTS). EMC uses these operational NESDIS wind products in their global and regional data assimilation/numerical forecast systems. NESDIS recently completed the effort to reformat the winds in WMO-sanctioned BUFR format. Current work involves the investigation of a slow bias seen in water vapor winds.

The newest satellite wind products include the low-level high-density visible satellite winds. During the daylight hours, visible channel data can be used to track cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent image sampling (15-30 minutes nominally; higher in special rapid scan modes). The visible channel can depict lower tropospheric cumuliform tracers in areas not covered by opaque cirrus. In terms of tropical cyclones, visible winds can depict the low level flow in the outer storm vortex region, which is an important area in assessing storm motion. The GOES satellites have an atmospheric sounder that includes two water vapor channels centered at 7.0 μm and 7.3 μm. These sounder channels can be employed as surrogate imagers to track water vapor features radiating from the lower layers of the troposphere. The weighting function of the 7.0 μm channel peaks around 450 mb and the weighting function of the 7.3 μm channel peaks around 550 mb. Water vapor winds generated from these two channels will compliment the imager-based cloud-drift and water vapor winds, resulting in an improved three-dimensional depiction of the wind field. The implementation of these new algorithms and the visible wind products into the operational environment at NESDIS began in 1999.

AVIATION

Aviation applications research focuses on detection and mitigation of hazards such as volcanic ash, in-flight icing, and fog and low ceilings. An encounter with an airborne volcanic ash cloud can result in millions of dollars in damage to jet engines and the airframe, as well as the risk of engine stalls. Therefore, avoiding these hazards is critical. Remote sensing is the primary means of identifying and tracking volcanic ash clouds. In-flight icing causes significant aerodynamic drag and 5-10 percent of all fatal air crashes for smaller, general aviation and commuter class aircraft. Fog and low ceilings are a major reason for aviation delays, resulting in >$2B annual economic loss, and account for about 25 percent of fatal aviation and maritime accidents.

ATMOSPHERIC MOISTURE AND STABILITY PRODUCTS

Research continues to improve the atmospheric moisture and stability products from the GOES East and GOES West sounder instruments. Precipitable water for three layers of the atmosphere (surface to 900 hPa; 900-700 hPa; and 700-300 hPa) are computed from the soundings. Total precipitable water (TPW) for the entire atmospheric column, from the Earth's surface to the top of the atmosphere, is also computed. These precipitable water products are particularly valuable for the short-term forecasting of precipitation-locating those environments favorable for heavy precipitation and flash floods, thunderstorms, and fog. Hourly updates of this data provide useful information for the EMC regional data assimilation systems and for weather forecasters in the field. EMC currently uses the GOES precipitable water retrievals as input to Eta Data Assimilation System (EDAS), which provides the initialization for the Eta forecast model. NESDIS is currently aiding EMC with running global and regional model impact analyses to improve and optimize the use of the GOES derived products in numerical weather prediction schemes.

As of July 8, 2003, the hourly cloud top information from the GOES sounder data is being assimilated into the operational National Centers for Environmental Prediction (NCEP) Eta Data Assimilation System (EDAS). The regional Eta model and the Rapid Update Cycle (RUC) model both assimilate GOES sounder cloud information to help improve the initial moisture and cloud field. In addition to the moisture products, numerous atmospheric stability indices can be computed from measurements made by the GOES sounder instrument. Two stability indices, the lifted index (LI) and CAPE index, are computed on a routine basis. Since these indices are produced hourly, sequential images of these derived quantities clearly show the diurnal and dynamic changes associated with weather events.

So, in addition to providing these data to EMC for use in numerical weather prediction models, the graphical representation of these products allows for the looping of the products in time. This capability aids NWS forecasters in the field to understand the time evolution of severe storms. For example, several (lifted index, total precipitable water, and cloud-top information, etc.) of these derived images are operational and sent to the NWS AWIPS (Advanced Weather Interactive Processing System) for forecaster use.

Because channel noise has improved with each successive sounder instrument, the GOES sounder moisture and stability products moved from a horizontal resolution of approximately 50 km to be approximately 10 km. The increased horizontal resolution offers exciting possibilities for enhanced use of these products in mesoscale forecasting. For example, the finer resolution improves the depiction of gradients in the retrieved products, such as moisture and atmospheric stability, which focuses attention to a local area of interest. These products can be viewed at http://www.orbit.nesdis.noaa.gov/smcd/opdb/goes/soundings/index.html#products and cimss.ssec.wisc.edu/goes/realtime. In addition, these products are available from GOES computer servers within OSDPD or at http://www.ssd.noaa.gov/PS/PCPN/pcpn-na.html#SNDR.

TROPICAL CYCLONE MONITORING

NESDIS continues to improve upon satellite-based techniques for estimating tropical cyclone positions and intensities, and for describing the internal structure of these storms. Recent sensors, such as AMSU and TRMM, among others, are being incorporated into the NESDIS operational tropical program, which supports the NWS and DOD hurricane programs. Real-time imagery and NESDIS tropical text messages can be viewed at www.ssd.noaa.gov/SSD/ML/real-time.html. Research is also being performed to improve the forecasts of tropical cyclone formation and intensity change by making better use of satellite observations.

PRECIPITATION ESTIMATES

Estimates of precipitation from satellites provide a valuable supplement to information from radar and rain gauges. This information is particularly useful for such phenomena as tropical systems that are still outside the radar umbrella. For monitoring of short-term rainfall events, the primary operational algorithm is the Hydro-Estimator (H-E), which provides estimates of instantaneous rain rate from GOES infrared data every 15 minutes over the CONUS and experimentally produces estimates worldwide. The H-E adjusts its computed rain rates for moisture availability, sub-cloud evaporation, orographic uplift, and other fac-

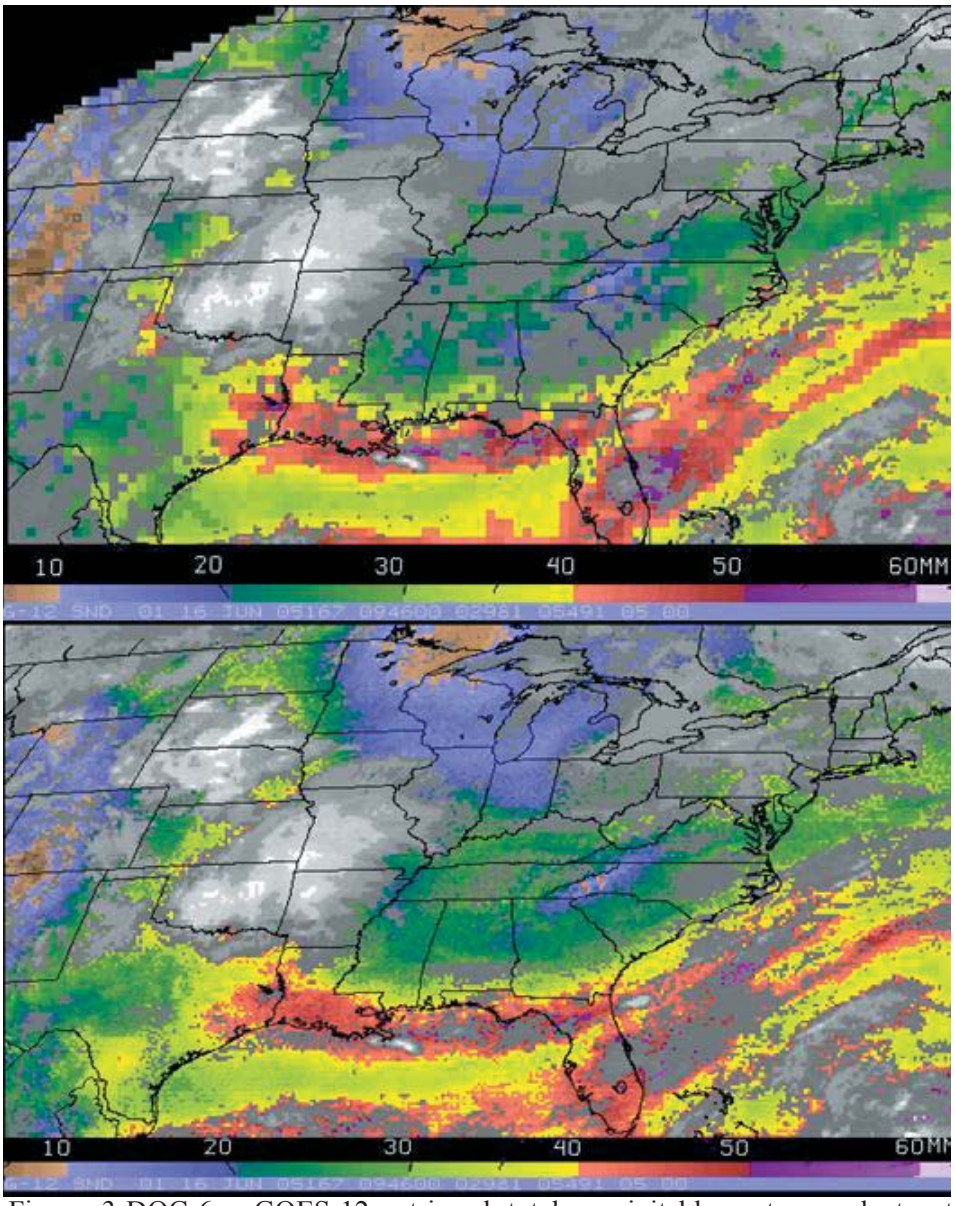


Figure 3-DOC-6. GOES-12 retrieved total precipitable water products at approximately 50 km resolution (top) and approximately 10 km resolution (bottom)

tors using data from operational numerical weather prediction models run at NCEP. Another algorithm approaching operational status is the GOES Multi-Spectral Rainfall Algorithm (GMSRA), which uses four of the five GOES Imager channels for more precise identification of raining areas. An experimental algorithm called the Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) attempts to combine the relative strengths of infrared-based and microwave-based precipitation algorithms to produce a more accurate result than could be achieved using GOES data alone. Real-time graphics of these and other algorithms plus real-time validation statistics are available at http://www.orbit.nesdis.noaa.gov /smcd/emb/ff/; in addition, the H-E is available to NWS field forecasters once per hour via AWIPS. In the near future, both the H-E and GMSRA will be available on AWIPS every 15 minutes, and coverage will be expanded to Hawaii and Puerto Rico.

In addition to short-term rainfall monitoring, longer-term precipitation analyses are created using microwave data from an improved AMSU-B/MHS algorithm and the AMSR-E. The AMSU-B/MHS products, which also include cloud properties and other related information, can be obtained at http://www.osdpd.noaa.gov/PSB/IMAGES/MSPPS_day2.html. These include estimates of equivalent snow water content and discrimination of falling rain from falling snow. Rainfall estimates from the DMSP SSM/I instrument also continue to be produced in cooperation with the U.S. Air Force and U.S. Navy and can be accessed at http://www.osdpd.noaa.gov/PSB/SHARED_PROCESSING/SHARED_PROCESSING.html.

These rainfall products are also used in direct forecasting applications. The Hydro-Nowcaster (H-N) extrapolates H-E estimates forward in time up to 3 hours based on storm cell movement, and the resulting 0-3 hour nowcasts are available at http://www.orbit.nesdis.noaa.gov/smcd/emb/ff/hn.html. Meanwhile, forecasts for 24-hour rainfall from tropical systems that are about to make landfall are produced operationally for the entire globe by extrapolating microwave-based estimates of rainfall from the (SSM/I, AMSU-B/MHS, or TRMM Microwave Imager) along the predicted storm track. These estimates are available at http://www.ssd.noaa.gov/PS/TROP/trap-img.html. Efforts are underway to produce an ensemble version of TRaP to enhance its accuracy and utility to forecasters.

MICROBURST PRODUCTS

Convective storms can pose serious threats to life and property. Of great concern are those storms that produce downbursts, defined as strong convective downdrafts that result in an outburst of damaging winds on or near the Earth's surface. In addition, downbursts are a hazard to aircraft in flight, especially during takeoff and landing phases. In order to assist the operational forecaster in the prediction of

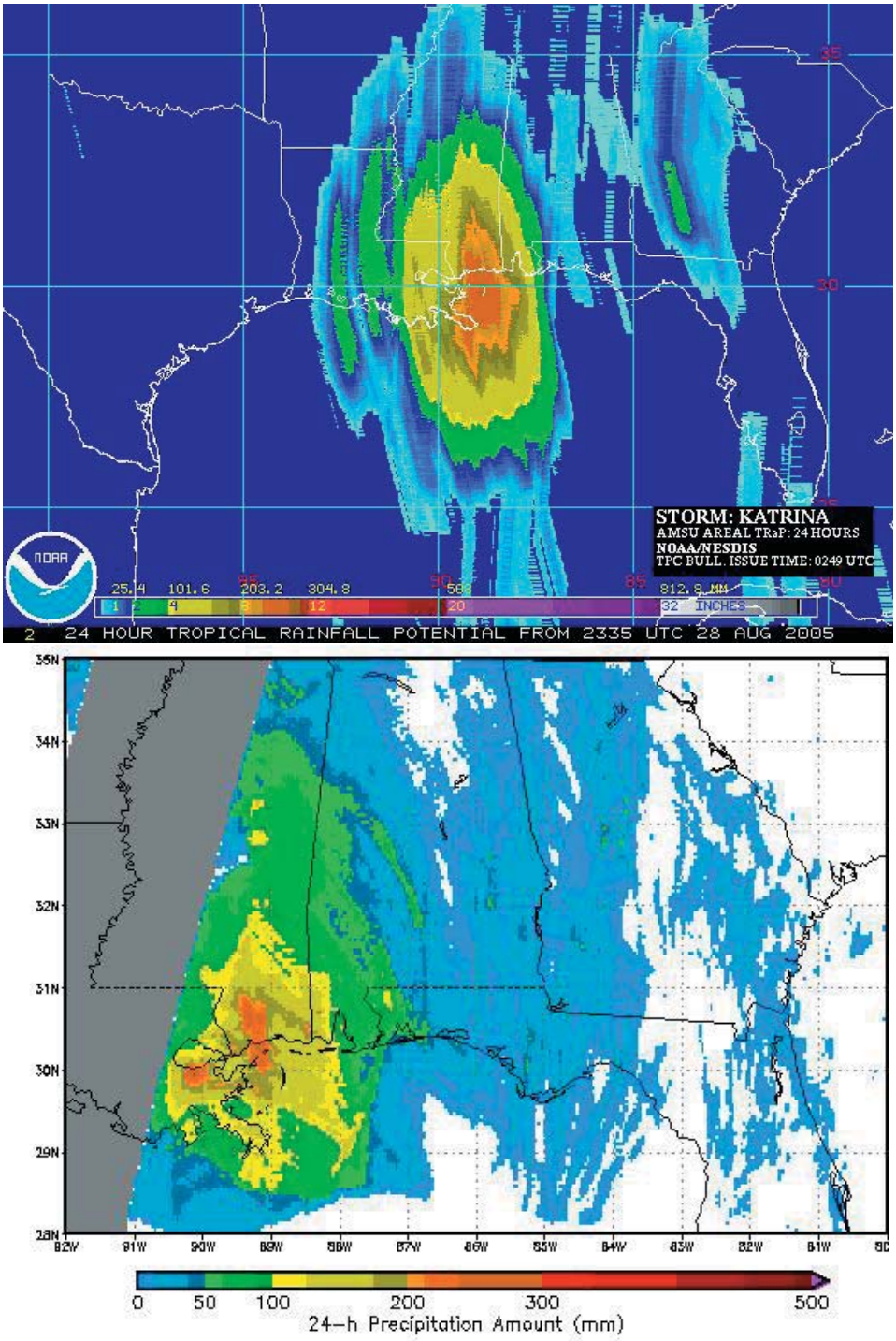


Figure 3-DOC-7. Tropical Rainfall Potential (TRaP) forecast for Hurricane Katrina (top) and corresponding Stage IV radar/rain gauge estimates (bottom) for the 24 hours ending 0000 UTC 30 August 2005. Data over the western portion of the Stage IV image are missing due to storm-related communications outages at the Lower Mississippi River Forecast Center (LMRFC) where that region's Stage IV estimates were produced.

this type of hazardous weather event, GOES sounder-derived microburst products have been developed and implemented. These sounder-derived products include the Wind Index (WINDEX) for estimating the magnitude of convective wind gusts, a Dry Microburst Index (DMI) for dry microburst potential, and Wet Microburst Severity Index (WMSI) for wet microburst potential.

The newest product of the suite, the Hybrid Microburst Index (HMI), indicates the potential for convective downbursts that develop in an intermediate environment between a wet type, associated with heavy precipitation, and a dry type associated with convection in which very little to no precipitation is observed at the surface. For more information visit http://www.orbit.nesdis.noaa.gov/star/Pryor_K.php.

AIRCRAFT ICING

Several upgrades to the GOES aircraft icing product have been implemented. New thresholds for the Band 2-4 (3.9-10.7 micrometer) brightness temperature difference versus visible brightness count corrected for solar zenith angle were employed in September 2003, followed by inclusion of cloud top heights from the GOES Sounder Cloud Top Product in February 2004. The latter combination, referred to as ICECAP (Icing Enhanced Cloud-top Altitude Product), was made available on the Web in February 2004. Finally, a correction to reduce the over-detection of icing caused by thin cirrus was employed in September 2004, based on a technique that uses Bands 4-6 (10.7-13.3 micrometers). Probability of detection (determined from the NOAA Forecast Systems Laboratory's Real-Time Verification System) is now consistently in the 55-70 percent range for the Continental U.S.

FOG AND LOW CLOUDS

GOES-12 visible and IR data for a case of sea fog over the northeast U.S. in June 2003, was analyzed to determine if the fog could be discriminated objectively from other cloud types. The results were provided to the NWS Meteorological Development Laboratory, which is developing objective sea fog forecasting techniques using surface, model, and satellite data.

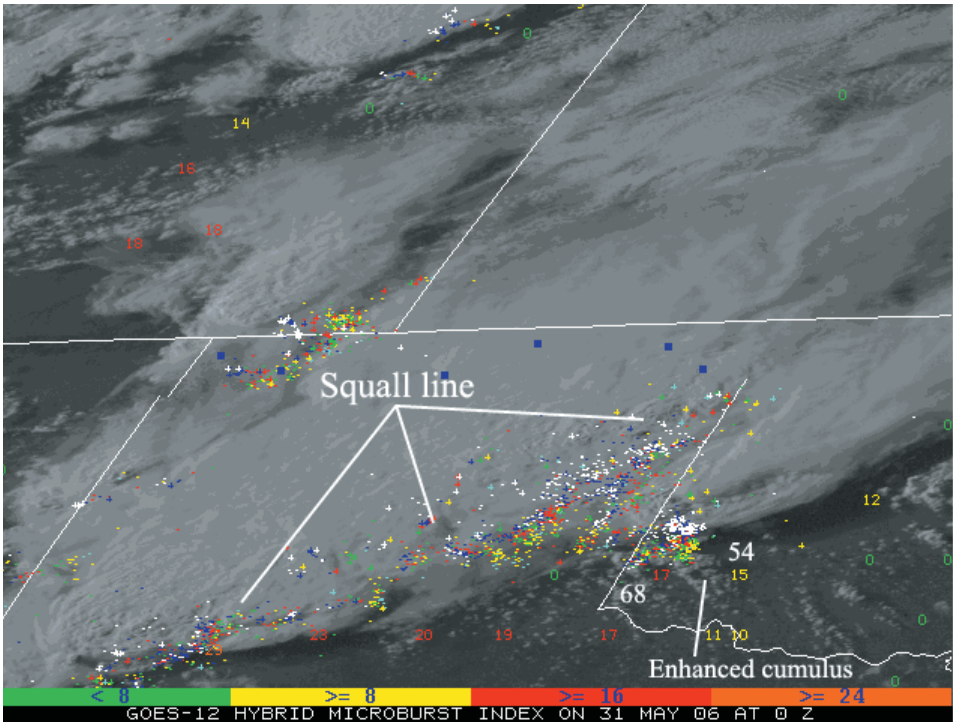


Figure 3-DOC-8. An Example of the GOES HMI Product.

GEOSTATIONARY SEA SURFACE TEMPERATURES

GOES-12 and GOES-11 are capable of producing sea surface temperatures (SST) over most of the Western Hemisphere nearly continuously. The accuracy and spatial resolution achieved with the GOES measurements are close to that achieved from the polar orbiting platforms, and GOES has a unique advantage of high temporal sampling frequency. Unfortunately, the trade-off of replacing the 12.0 µm channel with a 13.3 µm channel notably impacts the SST retrievals by eliminating the capability for daytime split-window retrievals, increasing the rms error by about 0.5 C. For the SST determination, the frequent sampling by GOES makes a more complete map of SST possible after clouds have moved on. Additionally, a change in scene temperature over a short period of time may indicate the presence of clouds, thereby enhancing cloud detection.

The abundance of GOES observations helps to maintain a balance between high-quality, cloud-free observations and good geographical coverage of SST estimates. GOES is enabling quantification of the diurnal variation of a radiometrically determined SST over large areas and long time periods. This quantification may have important implications in both numerical weather prediction and climate monitoring. NESDIS has been producing the GOES SST hourly in an experimental configuration since December 1998, from both GOES East and GOES West. A global SST product is produced every three hours; regional SST products are generated every hour. These products were recently implemented operationally and can be accessed as digital files from the GOES computer servers within OSDPD.

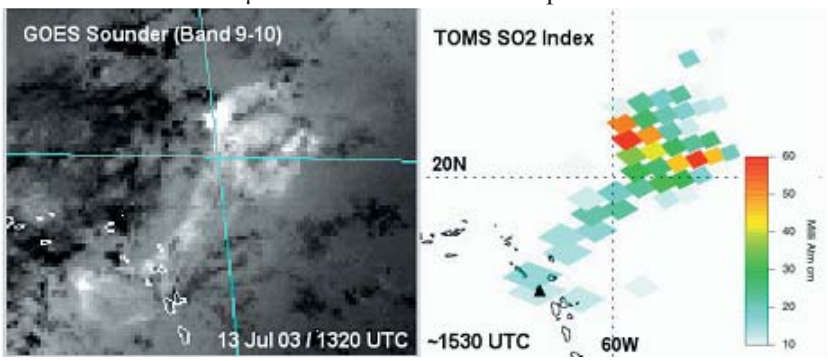


Figure 3-DOC-9. Comparison of GOES Sounder Band 9 minus Band 10 (left) versus the SO2 Index from the Total Ozone Mapping Spectrometer (TOMS) instrument (right) on July 13, 2003 are shown for the indicated times. The SO2 cloud was emitted from an eruption of Soufriere Hills Volcano, Montserrat (located shown in bottom of right hand image) that began around 0600 UTC, July 13, 2003.

VOLCANIC ASH

A new technique has been developed to mitigate the loss of the 12 µm IR band on GOES-12 to help track hazardous volcanic ash clouds. The technique uses IR channels centered at 10.7, 13.3, and 3.9 µm. Several recent eruptions of Soufriere Hill's volcano on Montserrat Island in the eastern Caribbean have shown that this new product is helpful in monitoring ash cloud emissions even at night. GOES-12 ash product can be viewed for several volcanically active regions at http://www.ssd.noaa.gov/VAAC/. The analysis of Moderate Resolution Imaging Spectroradiometer (MODIS) data from the NASA Terra and Aqua spacecraft has also yielded valuable information about optimum detection of volcanic ash using several spectral bands. A three-channel combination product based on the 8.6, 11, and 12 µm bands has been developed that provides effective discrimination of ash or sulfur dioxide gas with minimal false alarms. This algorithm could be applied to future products from NPOESS and GOES-R, which will have similar spectral bands. Volcanic

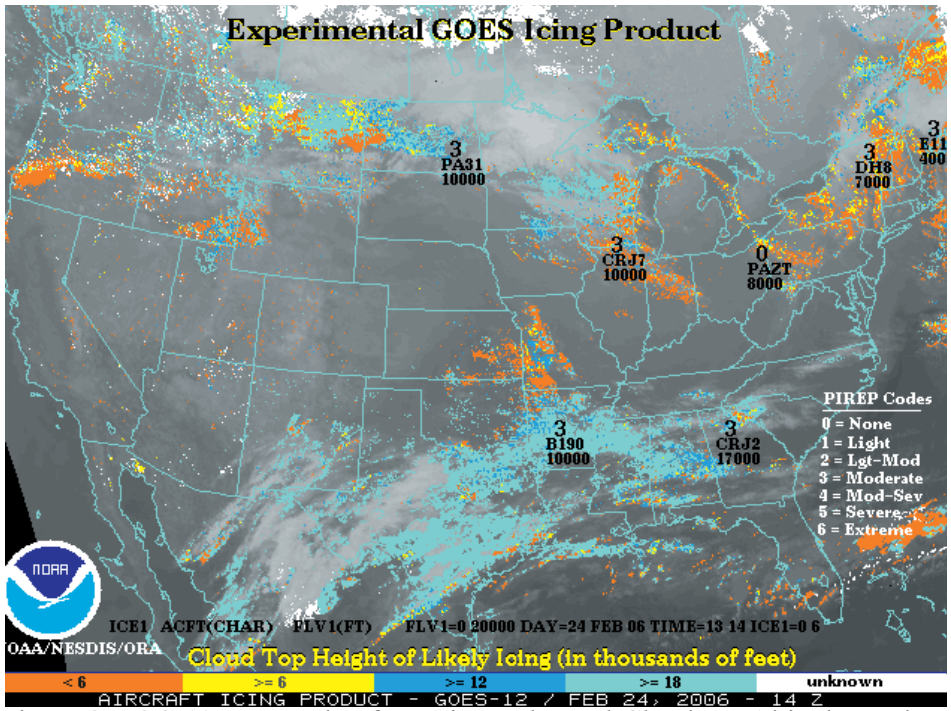


Figure 3-DOC-10. Example of an Icing Enhanced Cloud-top Altitude Product (ICECAP) image is shown, valid at 1700 UTC, on February 17, 2004. Areas of potential icing are color-coded in intervals of 6,000 ft to show maximum cloud top altitude. Pilot reports of icing are superimposed showing: numerical icing intensity (0 to 5), aircraft type, and altitude in feet. Severe icing (code 5) at 8,000 ft was reported in eastern Tennessee within two hours of the GOES product. Some icing (such as that shown in northwest U. S.) is obscured by high cloud layers and cannot be detected.

Ash Advisories (VAA) with associated Volcanic Ash Graphics (VAG) and ash forecasts are provided by NESDIS to the aviation community. The region of coverage is the continental U.S., Central America, northern South America to 10 degrees S, the Caribbean region, the Pacific Ocean south of Alaska and the Aleutians Islands, and, to the east of Japan, the Marianas Islands. The Volcanic Ash Advisory Center (VAAC) is located in Camp Spring, Maryland. GOES infrared and visible images, aerosol and sulfur dioxide products from NASA's Total Ozone Mapping Spectrometer (when applicable), and operational volcanic ash products for the Washington VAAC area of responsibility can be found at http://www.ssd.noaa.gov/VAAC/washington.html.

In addition to current operational products for volcanic ash, research into new and improved ways to detect volcanic ash are ongoing. Relevant bands from experimental multi-spectral and hyper-spectral satellite instruments, especially those spectral bands scheduled to be on future operational satellites, are being probed in the development of new products for the detection of volcanic ash. That is in addition to the improved spatial, temporal, and radiometric resolution offered by next-generation satellites.

FIRE MONITORING

Geostationary and polar-orbiting meteorological and environmental research satellites have been used to detect and monitor large active wildfires for over 20 years. Early work using the NOAA-6 AVHRR demonstrated how the different brightness temperature responses between the shortwave infrared (SWIR at 3.74 µm) and the long wave infrared window (LWIR at 10.8 µm) bands can be used to locate fires and estimate fire characteristics (e.g., instantaneous sub-pixel fire size and temperature). Since then algorithms have been developed at NOAA, NASA, and the Cooperative Institutes (UW-Madison - CIMSS, Colorado State University - CIRA) to utilize NOAA operational satellites (GOES Imager, POES AVHRR), research satellites (EOS MODIS, TRMM, ATSR, etc.), and defense satellites (DMSP OLS) to identify and monitor fires in near, real-time. In the mid-latitudes polar orbiting instruments (EOS-MODIS, POES AVHRR) provide several observations of a given region each day with more frequent observations near the poles. In routine mode the GOES Imager allows for fire monitoring every 15 minutes over CONUS and half-hourly throughout the rest of North, Central, and South America. Plans are underway to provide GOES Rapid Scan fire data every few minutes when available.

Since 2002, the NOAA NESDIS Satellite Service Division has provided fire products on-line via the Hazard Mapping System (HMS) (http://www.firedetect.noaa.gov). The HMS is an operational interactive processing system that integrates fire products from seven different sensors on NOAA (POES AVHRR, GOES Imager, DMSP OLS) and NASA (EOS MODIS) satellites to produce fire and smoke product analyses for the U.S. and parts of Canada and Mexico. Automated algorithms including the MODIS Fire and Thermal Anomalies team algorithm, the GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA), the AVHRR Fire Identification Mapping and Monitoring Algorithm (FIMMA), and the DMSP OLS algorithm are used to generate the fire products while smoke is delineated by an image analyst. Analyses are quality controlled by an analyst who inspects all available imagery and

automated fire detects, deleting suspected false detects and adding fires that the automated routines miss. Graphical, text, and GIS compatible analyses are posted to the HMS web site. All products are archived at NOAA's National Geophysical Data Center (http://map.ngdc.noaa.gov/website/firedetects).

Over the past 10 years, the use of these satellite derived fire products has grown appreciably with applications in hazards monitoring, fire weather forecasting, climate change, emissions monitoring, aerosol and trace gas transport modeling, air quality, and land-use and land-cover change detection. The user community includes government agencies (such as NOAA, NASA, EPA, and USFS), resource and emergency managers, fire managers, international policy and decision makers, educational institutions, and the general public. At NOAA's National Severe Storms Laboratory (NSSL) Storm Prediction Center (SPC) GOES WF_ABBA fire products provided by UW-Madison CIMSS are used in fire weather forecasting. The SPC Fire Weather Analysis Page (http://www.spc.noaa.gov/exper/firecom) integrates the GOES WF_ABBA fire product with other meteorological data and fire weather and danger indices (Haines, SPC LASI, Fosberg Index, etc.) to provide an overview of existing fires and fire danger in the continental U.S.. Since 2000, the Naval Research Laboratory in Monterey (NRL - Monterey) has been assimilating the GOES WF_ABBA and MODIS fire products (as of 2003) into the NRL Aerosol Analysis and Prediction System (NAAPS) in near, real-time to both monitor and predict aerosol loading and subsequent transport around the world (http://www.nrlmry.navy.mil/flambe/index.html). In Brazil, INPE/CPTEC has been assimilating the data into their air quality/transport models in real-time for several years (http://tucupi.cptec.inpe.br/meio_ambiente/).

Current research includes the development and implementation of a near,, real-time operational global geostationary fire monitoring network to monitor fires as they occur and capture the diurnal signature around the globe. Initially the GOES WF_ABBA is being adapted to Meteosat-8 and MTSAT-1R. Plans are underway to eventually adapt the WF_ABBA to FY-2C SVISSR (China), INSAT-3D (India), and the GOMS Electro N2 (Russia). This suite of geostationary sensors will enable nearly global geostationary fire monitoring with significant regions of overlap in Asia. Future activities include better utilization of current systems and long-term plans that ensure the capability to derive similar or improved and enhanced fire products with next generation operational polar-orbiting (NPOESS, Metop) and geostationary (GOES-R, MTG) series.

AIR QUALITY PRODUCTS

Since their inception, NOAA operational satellites have been monitoring the Earth's environment (e.g., Antarctic ozone hole) and climate (e.g., stratospheric ozone trends). While the need for this information continues to be met, NOAA's mission has expanded to include monitoring and forecasting air quality. Continuing detrimental impacts of air pollution (ozone and PM2.5) on human health and the economy led the U.S. Congress to issue various mandates to the Environmental Protection Agency (EPA) and NOAA to combat and mitigate pollution (e.g., H.R.4. Energy Policy Act of 2002, Senate Amendment). To meet the mandates, NOAA and EPA signed a Memorandum of Understanding (MOU) and a Memorandum of Agreement (MOA) in 2003.

The MOU calls for developing and deploying an operational air quality forecast system capable of issuing nationwide hourly air quality forecasts of ozone by 2007, and PM2.5 (particles smaller than 2.5 μm in diameter) by 2014. The NOAA/NWS has begun issuing operational ozone forecasts and experimental PM2.5 forecasts in the northeast in 2004, using the Eta-CMAQ (Community Multiscale Air Quality Modeling) system.

The MOA calls for cooperation in air quality research between NOAA and EPA by developing methods for using observations to improve predictions of air quality. NESDIS has begun supporting the MOA by providing near,real-time data such as ozone and aerosols to the NWS for operational air quality and UV Index forecasting applications.

The assimilation of satellite measurements of physical parameters (e.g., observations of temperature and moisture) into numerical weather prediction models to improve weather forecasts has grown tremendously in the last two decades and has proven to have a positive impact on weather forecasts. Satellite chemical data assimilation, on the other hand, is still in its infancy, especially since both operational air quality forecast systems and satellite sensor technology capable of measuring boundary layer pollutants are still evolving. While the ability to measure various tropospheric pollutants at the desired spatial resolution, temporal resolution, and accuracy remains a challenge, the need to exploit the measurements from current and soon-to-be launched sensors to monitor and improve air quality forecasting is imminent. NOAA/NESDIS is actively involved in using research satellite data (e.g., EOS Aura OMI and Aqua/Terra MODIS) to demonstrate the capabilities of enhanced sensors and prepare NOAA and its users for IJPS, NPOESS, and GOES-R datasets. EUMETSAT is launching the GOME-2 and IASI instruments, which are capable of measuring trace gases and aerosols, into a polar orbit with 9:30

A.M. equator crossing time. Products from these instruments are available to NOAA. NPOESS will have OMPS and CrIS sensors with similar capabilities and will fly with a 1:30 P.M. equator crossing time. The IJPS (~2006 and beyond) and NPP/NPOESS (~2009 and beyond) systems are expected to provide continuous monitoring of trace gases and aerosols into the 2020s.

Together, these sensors will have a capability to measure tropospheric column amounts of trace gases (ozone, nitrogen dioxide, formaldehyde, sulfur dioxide, carbon monoxide, etc.) in addition to aerosol products at spatial resolutions similar to forecast models. Routine observations on such high spatial and temporal scales cannot be matched by any ground observations and are critical for monitoring and assimilation applications. NOAA/NESDIS is currently developing GOME-2 ozone products for near,real-time dissemination to users (Table 3.2).

The ABI and the HES instruments on the next generation Geostationary Environmental Operational Satellite (GOES), Series R, will provide unprecedented information on air quality. Plans are currently underway to develop various air quality products for the Americas at temporal resolution ranging from 5 to 60 minutes for the imager and sounder respectively. These products are expected to become operational after the launch of GOES-R in 2013 (Table 3.3).

CURRENT PRODUCTS AND APPLICATIONS

Aerosol Optical Depth (AOD). Satellite measured AOD has been shown to be a good proxy for pollution monitoring especially when long-range transport is involved. NESDIS/STAR has been providing to its users GOES AOD product in near, real-time since 2003. This product is available at 30-minute intervals and 4 km × 4 km spatial resolution during the sunlit portion of the day. EPA and NWS have been using the product for monitoring and forecasting applications.

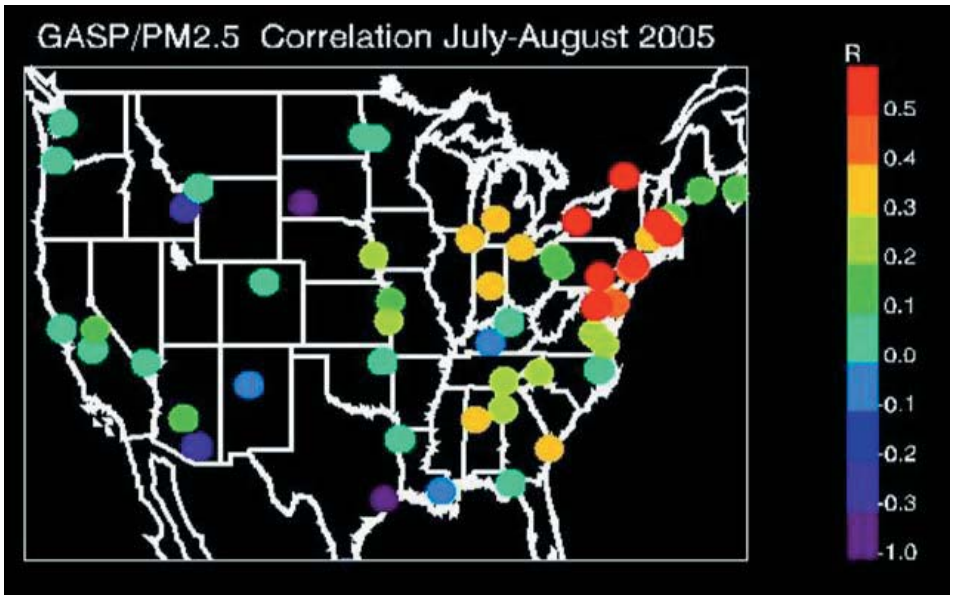


Figure 3-DOC-11. Shows mean bias between satellite measured aerosol optical depth and NWS experimental forecast during July 15 - August 15, 2004.

Emissions. Emissions from both natural and anthropogenic sources contribute to poor air quality. Biomass burning (prescribed and wild fires) release huge amounts of smoke (primary particulates dominated by black carbon) and trace gases into the atmosphere. Power plants, oil refineries, and other industrial sources release NO2 (nitrogen dioxide), H2CO (formaldehyde), SO2 (sulfur dioxide), and other organic compounds leading to poor air quality as well. The EPA compiles a National Emissions Inventory (NEI) every year for a number of critical environmental management and policy activities such as tracking the Clean Air Act and Clean Air Interstate Rule. Emissions data are used to determine trends over time as well as to initialize air quality forecast models. One of the primary sources of uncertainty in air

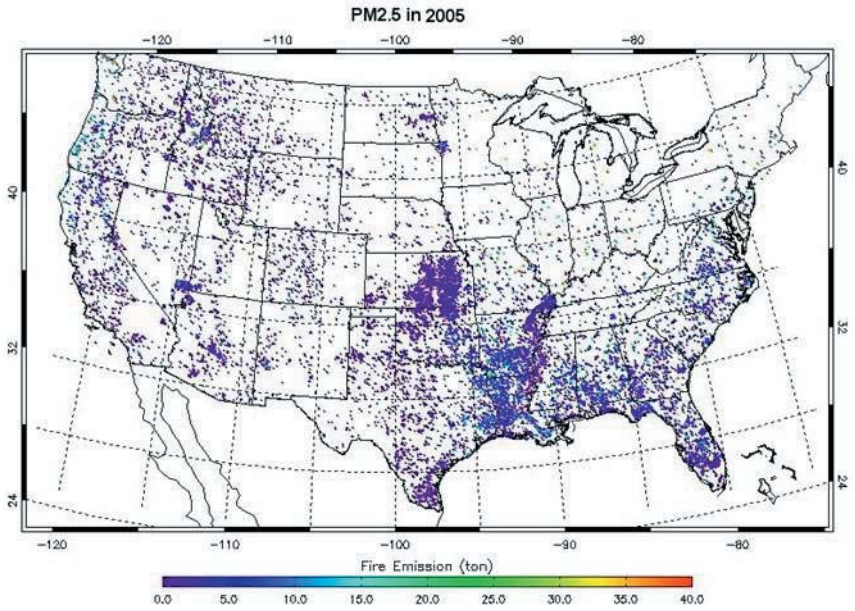


Figure 3-DOC-12. Annual PM2.5 emissions for 2003 from biomass burning events as observed by GOES-12 Imager

TABLE 3.2 TRACE GAS AND AEROSOL PRODUCTS FROM OPERATIONAL POLAR-ORBITING SATELLITES

Pollutant	**Location**	**Satellite (Sensor)**	**User/Application**
NO_2	Troposphere	IJPS (GOME-2)	NWS – Assimilation NWS – Forecast model evaluation EPA – Assessment work (emissions) Model evaluation NOAA – Model evaluation
SO_2	Troposphere Stratosphere (volcanic)	IJPS (GOME-2) NPP/NPOESS (OMPS) IJPS (IASI) NPP/NPOESS (CrIS)	NWS – Forecast model evaluation EPA – Model evaluation NOAA – Model evaluation
H_2CO	Troposphere	IJPS (GOME-2) NPP/NPOESS (OMPS)	NWS – Forecast model evaluation EPA – Assessment work (emissions) Model evaluation NOAA - Model evaluation
CHOCHO	Troposphere	IJPS (GOME-2)	EPA – Assessment work (emissions)
O_3	Column	IJPS (GOME-2) IJPS (IASI) NPP/NPOESS (OMPS) NPP/NPOESS (CrIS)	NWS – Assimilation
O_3	Profile (stratosphere)	IJPS (GOME-2) NPP/NPOESS (OMPS)	NWS – Assimilation
CO	Troposphere	IJPS (IASI) NPP/NPOESS (CrIS)	EPA – Assessment work (emissions) NWS – Forecast model evaluation
CH_4	Column	IJPS (IASI) NPP/NPOESS (CrIS)	EPA – Assessment work (emissions)
CO_2	Column	IJPS (IASI) NPP/NPOESS (CrIS)	NOAA – Climate monitoring
BrO	Stratosphere	IJPS (GOME-2)	NOAA – Climate monitoring NASA – Climate monitoring
OclO	Stratosphere	IJPS (GOME-2)	NOAA– Climate monitoring NASA – Climate monitoring
Aerosols	Troposphere	IJPS (GOME-2) IJPS (IASI) NPOESS (OMPS) NPOESS (CrIS) NPOESS (VIIRS) NPOESS (APS)	NWS – Assimilation NWS – Forecast model evaluation EPA – PM2.5 monitoring

TABLE 3.3 GOES-R BANDS AND PRODUCTS

Sensor	Bands	Product	Applications
ABI	0.47μm, 0.86μm, 2.1μm	Aerosol optical depth, type (dust vs. non dust), particle size (effective radius), and fraction of fine mode vs. coarse mode	EPA – PM2.5 monitoring NWS – PM2.5 forecasting NIEHS – Health impacts CDC – Health impacts
ABI	9.6μm	Total column ozone	FAA – Clear-air turbulence NWS – Ozone forecasting
ABI	3.9μm, 11μm	Fire location, size, intensity and carbon consumption Aerosol and trace gas emissions	EPA – Assessments NWS – Forecasting
ABI	11μm, 12μm	Dust detection	EPA – Monitoring
HES	800 – 1000 cm^{-1}	Dust loading and height Volcanic ash detection, amount and height Smoke plume height	VAAC – Advisories EPA – Monitoring NWS – Forecasting
HES	1650 – 2250 cm^{-1}	Carbon monoxide Methane	EPA – Assessments NWS – Forecasting NOAA – Climate
HES	950 – 1050 cm^{-1}	Ozone profile	NWS – Forecasting
HES	600 – 800 cm^{-1}	Ash cloud height Smoke plume height	VAAC – Advisories NWS - Forecasting
HES	1100 – 1200 cm^{-1}	Sulfur dioxide	VAAC – Advisories

quality forecasts comes from the uncertainties in these emissions. NESDIS/STAR developed algorithms to derive emissions of PM2.5 and trace gases from biomass burning. These products will be provided to NWS in near, real-time for assimilation into air quality forecasting models.

3D Air Quality Mapping System. Satellite data have been very useful in diagnosing long range transport, primarily because this occurs in free troposphere and is more easily detected by satellites. NOAA is interested in the issue of entrainment of pollutants transported from long distances into the boundary layer and the impact on local air quality. NASA launched CALIPSO in April 2006, which has a Lidar on board that can detect tropospheric vertical profiles of aerosol backscatter ratio. These measurements combined with column aerosol optical depth retrievals will become very valuable in providing a three-dimensional look at pollution plumes. Additionally, integrating data from multiple sensors will optimize the information on aerosol type, location in space (horizontal and vertical scale), and time (GOES aerosol observations have a refresh rate of 30 minutes). Satellite Meteorology and Climatology Division (SMCD) scientists are co-investigators of the NASA funded 3D Air Quality System project which will investigate combining information from various sensors to build 3D air quality measures that can be applied to studying linkages between human health and air quality.

Numerical Modeling. The NWS has already begun issuing ozone forecasts for the northeast and conducting experimental PM2.5 forecasts. They currently use the Eta-CMAQ modeling system and will soon migrate to the WRF (Weather and Research Forecast) model with integrated meteorology and chemistry. Primary sources of uncertainties in model forecasts are from uncertainties in initial/boundary conditions and emissions. Satellite data, when assimilated into the models, have the potential to improve forecasts by providing initial/boundary conditions and constraining emissions. In situ data collected during field campaigns will be very useful in verifying the forecasts and diagnosing various sources of uncertainties in both models and satellite data. Chemical data assimilation is in its infancy; only ozone has been successfully assimilated and demonstrated to have an impact on surface ozone. Methodologies to assimilate other trace gases (e.g., NO2) and aerosols in an operational forecast mode are yet to be developed.

Other Applications. Measurements of trace gases and aerosols from a geostationary platform bring about unique applications due to their high temporal sampling. For example, a total ozone product available at an hourly refresh rate from GOES-R will be a very useful product for the Federal Aviation Administration (FAA) to monitor clear air turbulence. Similarly, an ability to monitor signatures of dust loading, type, and vertical location provides unprecedented information for air quality and climate applications. The ability to distinguish between different aerosol types is extremely important for air quality monitoring and forecasting applications. GOES-R trace gas retrievals such as O3, CO, CH4, CO2 are expected to serve the needs of air quality, climate, and health community from a monitoring and modeling perspective.

While the currently used ozone data in the models and monitoring come from polar-orbiting satellite sensors, the capability of geostationary satellites to provide synoptic ozone measurements on similar time and spatial scales as existing operational air quality models and surface networks is essential for proper characterization of ozone in the troposphere. Specifically there is a need for this data from geostationary satellites because hourly measurements:

- Provide more cloud-free data which are necessary for providing constraints on tropospheric ozone and are essential for the EPA to understand relationship between tropospheric column ozone and observed surface ozone from ground monitors under varying meteorological conditions.
- Reduce aliasing of synoptic scale transport patterns relative to polar-orbiting sensors, which is essential for capturing upper tropospheric ozone variations associated with folding events.
- Are essential for the EPA to monitor diurnal changes.
- Are needed for surface energy flux algorithms, photolysis rate calculations in air quality models, and other similar applications (specifically total ozone measurements).

Atmospheric Winds. Atmospheric motion vectors (AMVs) derived from a sequence of satellite images are an important source of global wind information, particularly over the world's oceans and more remote continental areas where conventional weather observations are lacking in time and space. These data are routinely used by the major Numerical Weather Prediction (NWP) centers in the world and assimilated into regional and global NWP prediction models. These data are also made available to NWS forecasters responsible for providing the public with day-to-day weather forecasts. In addition, these products are distributed over the Global Telecommunication System (GTS) and the NWS Advanced Weather Interactive Processing System (AWIPS).

AMVs are typically derived from the GOES imagery providing coverage from approximately 60 degrees S to 60 degrees N. The current operational GOES wind products include infrared (IR) cloud-drift winds, water vapor (WV) motion winds, and visible (VIS) cloud-drift winds. Figure 3-DOC-12

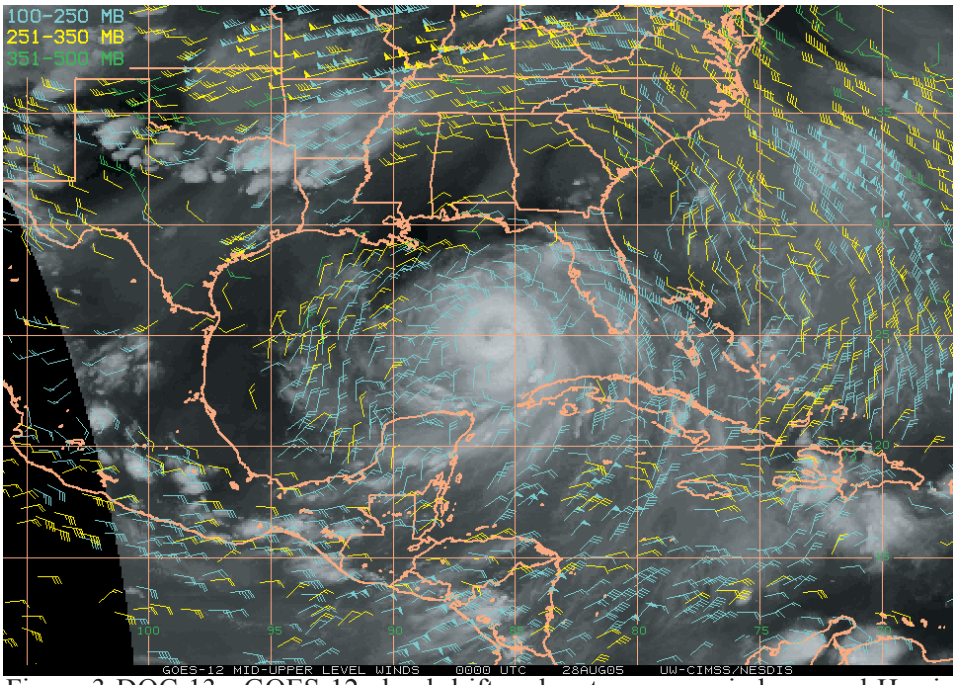


Figure 3-DOC-13. GOES-12 cloud-drift and water vapor winds around Hurricane Ivan at 18Z on September 13, 2004 overlaid on composite, true color image generated from multiple GOES imager channels.

shows an example of GOES-12 cloud-drift and water vapor winds around Hurricane Ivan at 18Z on September 13, 2004.

The capability to derive AMVs from measurements made by the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard the polar-orbiting Terra and Aqua satellites was first developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and is based upon established methodologies and algorithms used to derive wind observations from the GOES series of satellites. MODIS cloud-drift and water vapor wind observations from Terra and Aqua provide unprecedented coverage in the polar regions of the globe, areas where wind observations are sorely lacking. Figure 3-DOC-13 shows an example of the MODIS water vapor motion wind products in the Northern Hemisphere polar region.

In 2004, the MODIS winds capability was integrated within the existing operational NESDIS winds processing system. Significant modifications made to the algorithms included targeting from the middle image in the image triplet and using the National Centers for Environmental Prediction's (NCEP's) global forecast model grids as the first guess in the MODIS winds processing scheme. Targeting from the middle image in the image sequence had a significant impact on the pattern recognition/feature tracking process, which significantly improved the quality of the MODIS wind products. Experimental, near, real-time production of MODIS winds from Terra and Aqua was established at NESDIS and product datasets made available to the NWP user community. Near, real-time experimental MODIS wind products from Aqua and Terra were generated, distributed, and archived in support of two MODIS Winds Special Acquisition Periods (MOWSAPs) aimed at providing MODIS wind products to numerous NWP centers for subsequent model impact studies. MOWSAP-I covered November 5, 2003, to December 31, 2003, and MOWSAP-II covered July 5, 2004, to August 23, 2004.

NWP centers involved in assessing the MODIS winds during MOWSAP included: NWS/NCEP, European Center for Medium Range Weather Fore-

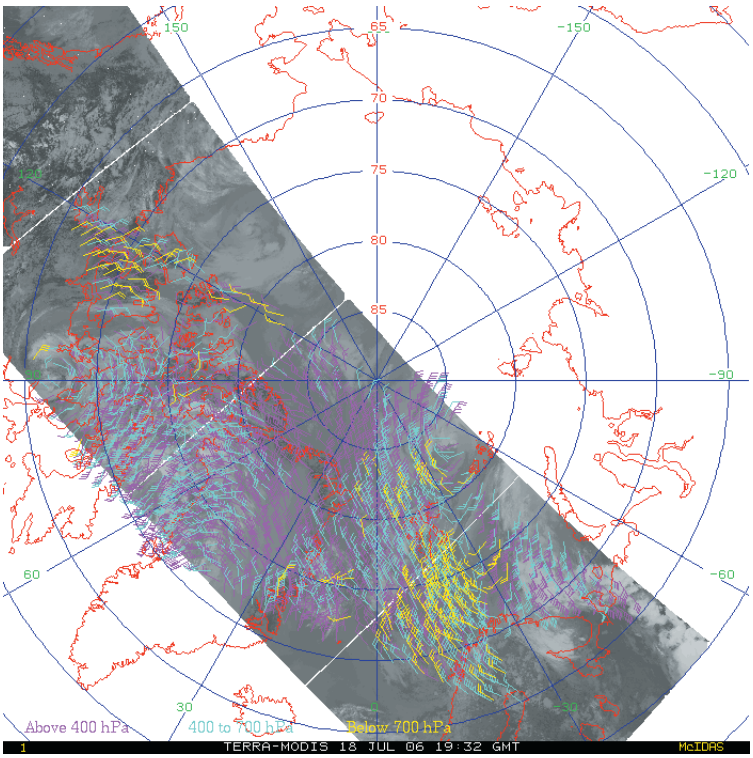


Figure 3-DOC-14. MODIS water vapor motion winds over the Northern Hemisphere polar region.

casting (ECMWF), United Kingdom Meteorological (UKMET) Office, Canadien Meteorological Center (CMC), the German Weather Service, and NASA's Global Modeling Assimilation Office (GMAO). Forecast impact results from all NWP centers involved in the MOWSAP test periods showed that the MODIS wind products have a significant positive impact on forecast accuracy in the Arctic and Antarctic, as well as in the extra-tropics of both the Northern and Southern Hemispheres. Given the positive forecast impact results, the MODIS winds capability was transitioned to OSDPD/Satellite Services Division (SSD) where they routinely provide MODIS AMVs to the NESDIS user community.

Areas of active AMV research include: upgrades to the MODIS AMV processing, improved quality control of AMVs, investigating optical flow approaches to the problem of feature tracking, and the derivation of AMVs from rapid scan GOES imagery.

In the U.S., GOES has been used in operational forecasting for quite some time. Forecasters recognize the additional detail that can be captured from more frequent imaging in events associated with rapidly changing cloud structures. The value of more frequent imaging is demonstrated by the inclusion of a 15-minute update cycle over the Continental United States (CONUS) sector in the current GOES schedule and by the multitude of special NWS operational requests for more frequent sampling at 7.5 minute intervals (Rapid-Scan Operations, RISOP). On occasion, special periods of Super-Rapid-Scan Operations (SRSO) have been requested by the research community. The SRSO allow limited-area coverage of one-minute interval sampling over meteorological events of interest.

Recently, special GOES RISOP periods have been collected during several field programs and research initiatives designed to maximize observational abilities in regions of high-impact weather events. Some examples include the NASA Tropical Cloud Systems Program (TCSP), the Atlantic Thorpex Regional Campaign (ATReC), and the TROpical Predictability EXperiment (TROPEX). In ATReC and TCSP, the datasets were used in real-time in mission planning and/or directing aircraft to targets of opportunity. In TROPEX, the datasets will be used in targeted observing strategy experiments run by modelers at the Naval Research Laboratory. In all three cases, the enhanced datasets are expected to be employed in case study analyses and numerical model impact studies.

Integrated Cal/Val Enterprise System. The users of numerical weather predictions require accurate calibration of satellite measurements. For satellite measurements having anomalies in radiances and/or large systematic biases, the data will be rejected during the data assimilation stage. It is also very difficult to use the satellite observations that are not quantified for their measurement precision. For climate studies, satellite instruments must be capable of measuring Earth system variables at high accuracy and stability over decadal (and ultimately, centennial) time scales. During a calibration workshop organized by NIST, NOAA, NPOESS-IPO, and NASA in November 2002, accuracy and long-term stability objectives for satellite measurement were established. The final report of the workshop defines the required absolute accuracies and long-term stabilities of global climate data sets, and it translates the data set accuracies and stabilities into the required satellite instrument accuracies and stabilities (e.g., for troposphere atmospheric temperatures, the measurement accuracy is 0.5 K and stability is 0.04 K/decade; for surface albedo measurement, the accuracy is 0.01 and stability is 0.002 K/decade). Those requirements pose tremendous challenges to the post launch calibration of satellite sensors.

NESDIS/STAR has an excellent track-record in supporting the operational calibration of radiometers on polar-orbiting environmental satellites, transferring research results to operations and performing advanced research in satellite instrument calibration. In addition to our heritage in on-board and vicarious calibration, in recent years we have developed many additional components such as inter-satellite calibration, on-orbit and prelaunch instrument characterization, and the incorporation of radiative transfer model calculations.

STAR also plays an important role in re-calibrating historical data to support climate studies, through the scientific data stewardship program. In recent years, STAR has developed comprehensive calibration/validation capabilities which are being incorporated into the Integrated Calibration and Validation enterprise System (ICVS). The vital components of the ICVS include prelaunch and on-orbit quantification of satellite instrument noise and on-line performance monitoring; linear and non-linear thermal calibration; on-board ultra-violet (UV), vicarious visible and near-infrared calibration; independent verification of radiances through inter- and intra-satellite calibration; and radiative transfer calculations to isolate biases and anomalous contributors to the biases. Today, we can quantify the on-orbit instrument noise and biases with little ambiguity, significantly reducing the uncertainties for the data users in direct radiance assimilation in numerical weather prediction, physical retrievals, and climate monitoring and reanalysis.

With the ICVS framework, STAR is now in an excellent position for leading and coordinating the WMO Global Space-based Intercalibration Calibration System (GSICS). The GSICS is to integrate observations and products

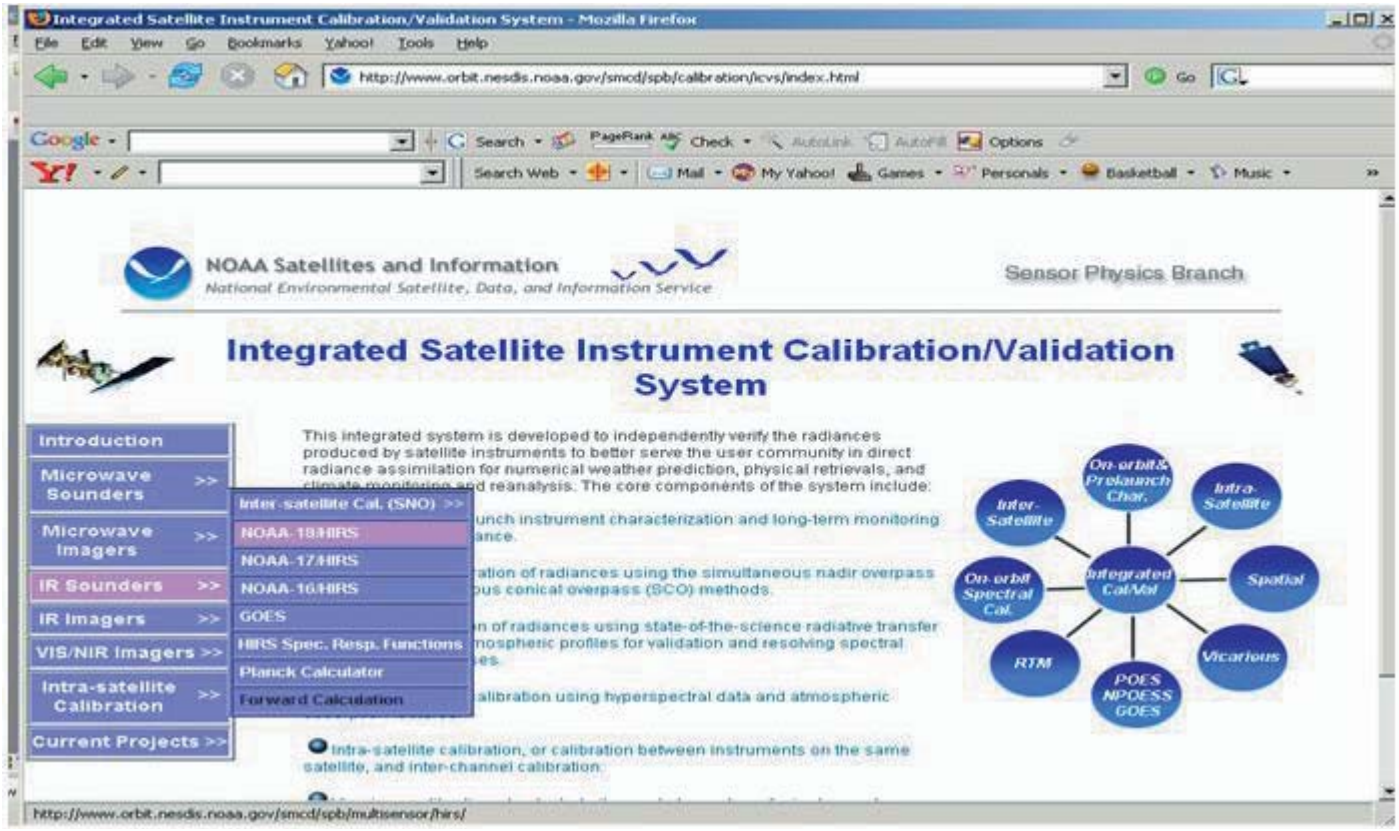


Figure 3-DOC-15. NOAA's Integrated Satellite Instrument Calibration/Validation System.

from different satellite systems through intercalibration. The intercalibration can quantitatively relate the radiances from different sensors viewing the same target and allow consistent measurements to be taken over the globe by all elements of the space-based observing system. Without inter-calibration of the space-based component of the World Weather Watch (WWW) Global Observing System and of GEOSS, the full benefit of the observations will not be realized for the environmental data stewardship.

During the 2005 hurricane season, the ICVS was first applied for NOAA-18 on-orbit verification and led to an early delivery (45 days after NOAA-18 launch) of high quality satellite observations for uses in NOAA computerized models that significantly improve the accuracy and extend the range of weather prediction for severe storms such as hurricane track, wind damage, and surface flooding. This results in an overall savings equivalent to 2.5 percent of the total cost of the satellite with a lifespan of 5 years (~200 million dollars) or ~5 million dollars. With the ICVS, STAR scientists are able to provide an accurate analysis of the root cause of the NOAA-18 HIRS/4 anomaly and provide mitigation strategies for containing the noise and reducing the risk for future

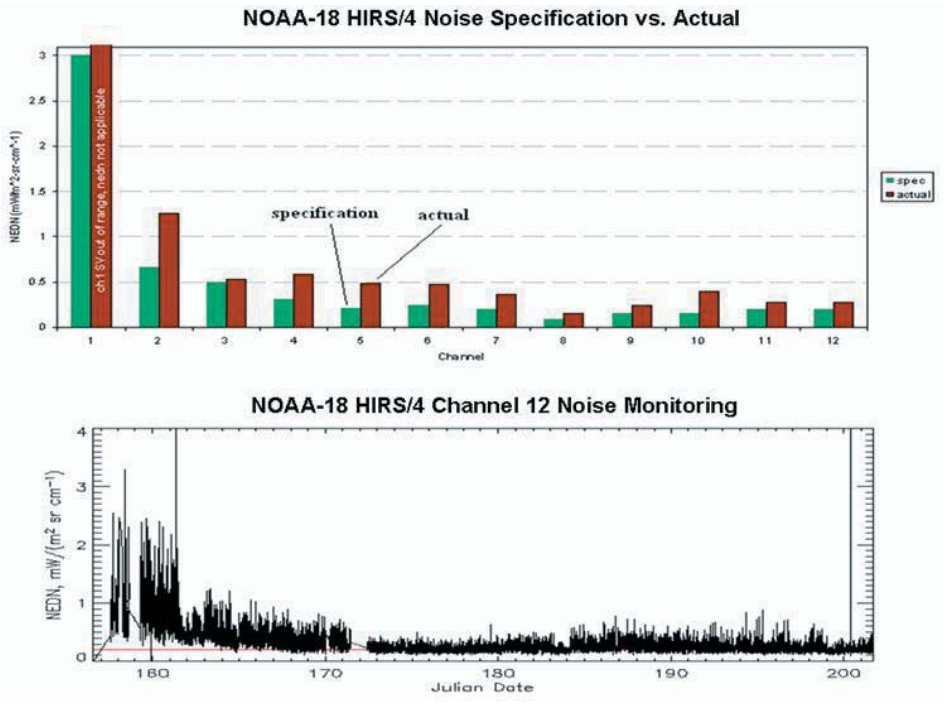


Figure 3-DOC-16. ICVS was first applied for NOAA-18 on-orbit verification.

launches (see Figures 11 and 12).

The ICVS is also providing a root-cause analysis and diagnostics for DMSP Special Sensor Microwave Imager and Sounder (SSMIS) radiance anomalies. The SSMIS is the first conically-scanning microwave instrument that measures the Earth's radiation from 19 to 183 GHz and presumably provides improved atmospheric temperature and water vapor sounding under all weather conditions. It is a key sensor for NPOESS risk reduction studies. Unfortunately, the main reflector from the SSMIS antenna subsystem emits some radiation and contaminates the Earth scene signals. In addition, the warm calibration target is intruded by direct solar radiation and other stray lights, producing anomalous calibration counts in several latitudinal zones. These contamination sources cause anomalies in SSMIS radiances in Temperature Data Records (TDR) and Sensor Data Records (SDR), which change with latitude and season. As part of the ICVS, the SSMIS anomaly distributions (locations and magnitudes) are detected and corrected during the calibration process. Therefore, the SSMIS data after the NOAA recalibration and processing is of improved quality for operational applications in weather and climate models (see Figure 3-DOC-17).

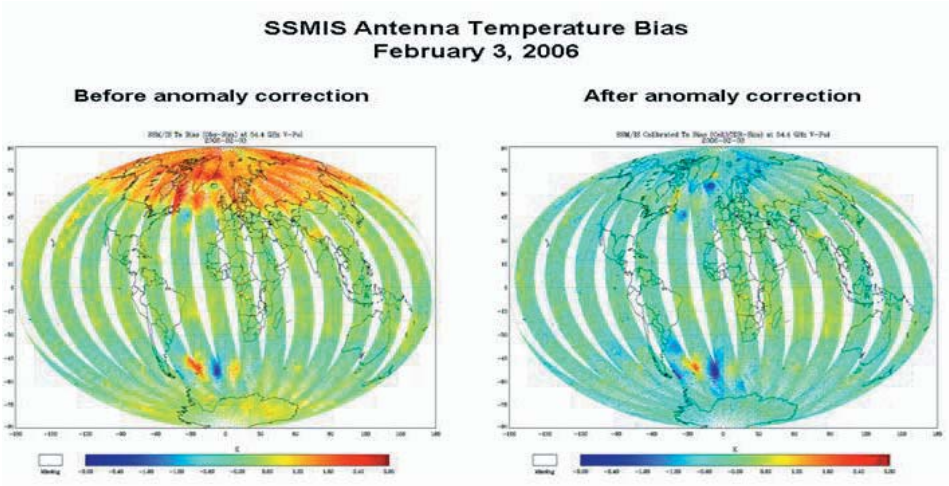


Figure 3-DOC-17. SSMIS anomaly distributions (locations and magnitudes) are detected and corrected during the calibration process.

NPP/NPOESS Sensor Calibration, Product Developments, Enhancement, and Validation. STAR scientists continue to play an important role in the evaluation of NPOESS contractor sensor design and retrieval methods. This group provides the end-to-end support to NPOESS program from instrument calibration to product validation and applications. STAR scientists have also been participating in NPOESS operational algorithm teams (OAT) and all phases of the NPOESS sensor calibration process to assure that radiometric performance of NPP/NPOESS instruments will meet the scientific needs of NOAA and other agencies.

STAR scientists have also been providing significant technical support to the prelaunch calibration of major NPOESS instruments in the last few years. As early as 2001, STAR scientists contributed to the technical design of the several major NPOESS instruments and supported the investigation of prelaunch calibration issues using comparisons with current POES instruments and evaluating how they affect the calibration traceability between POES and NPOESS. Currently, STAR is providing technical examination of the calibration accuracy, NE T, and nonlinearity for several instruments such as ATMS.

In the NPOESS post-launch calibration, STAR will focus on the characterization of on-orbit instrument noise and biases of all NPOESS instruments using the STAR integrated cal/val enterprise system and develop an on-line instrument performance trending system that monitors a selected number of key parameters.

It is critical to the NPOESS program and to the scientific community at large that the contractor scientific algorithms are assessed independently during the pre-launch phase so that potential corrective measures are taken early, avoiding sub-optimal results later in the process and/or delays in delivering the real-time data to weather centers and other customers after launch has occurred. STAR scientists have proposed a vigorous assessment of radiometric and geophysical performances of NPP/NPOESS instruments, in both pre-launch and post-launch stages. Further assessments will be made to check the robustness and the timing requirements for an operational use.

The contractor algorithms are being extensively compared in simulation and with real data, with operational products developed by STAR from EOS, POES and DMSP platforms. STAR is a center with various proxy data sets and testbeds through simulations and real measurements for NPOESS instruments. NPOESS contractor algorithms are now being run at the STAR systems and assessed with the proxy data. Since the STAR team have dual experience with both the contractor algorithms and in the operational algorithms running at NOAA, there have been rapid advances in the assessment of the contractor's algorithms performances.

NPOESS "test bed" data sets. STAR scientists continue to play an important role in the evaluation of proposed contractor sensor design and retrieval

methods during the ongoing selection process for NPOESS. STAR scientists have created a variety of test bed data sets that are being used in the algorithm evaluation process. This is accomplished through participation in operational algorithm teams with the long-term goals of assuring capability to meet the requirements of all Environmental Data Records. Ozone evaluation, calibration, and validation activities took place for the new Solar Backscatter Ultraviolet Instrument (SBUV/2) with the launch and successful checkout of NOAA-17. A new ozone profile retrieval algorithm has been developed by NASA and is now incorporated into SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-14, NOAA-16 NOAA-17, and NOAA-18 and with the TOVS instruments on NOAA-14, NOAA-15, NOAA-16, NOAA-17 and NOAA-18. Experimental high temporal ozone products are also being produced from the GOES-12 sounder channels. Monitoring is limited to North America. Preliminary results show the GOES values are comparable to amounts from the Total Ozone Mapping Spectrometer and ground-based measurements.

Land Surface Parameters for Use in Weather Forecast Models. Satellite-derived fields of land surface characteristics are being produced operationally for use in NWP models. These include radiation products delivered in near, real-time as forcing variables; surface characteristics, such as fractional green vegetation and albedo, that specify model lower boundary conditions; and validation quantities, such as surface temperature. These products are meant to help the NWP models maintain better soil moisture fields which in turn results in better near surface temperature and humidity forecasts, and better precipitation forecasts. These fields now include POES-based (SSM/I and AMSU) estimates of surface emissivity, snow cover, sea-ice extent and concentration, land surface skin temperature, and soil wetness. Development of snow depth is underway. Plans are in the making to develop the AMSU-A Snow Water Equivalent (SWE) product for operational use. Forward models for surface emissivity at various microwave frequencies have been developed and are being tested in the forecast models. Algorithms to determine clear sky ice surface temperatures have been developed and delivered to Atmospheric Environment Service, Canada for evaluation. New techniques such as automatic edge detection and incorporation of new sensors such as AMSU and NASA's MODIS are in development to improve operational production of daily snow and ice extent products. These products are delivered as digital files to NWP models and to the NWS Climate Prediction Center and other users. Graphical imagery of operational northern hemispheric snow cover can be found on the Internet at www.ssd.noaa.gov/SSD/ML/real-time.html #SNOW.

Clouds from AVHRR. Within STAR, methods to derive information on cloudiness have been developed and applied to data from the AVHRR. The Clouds from AVHRR Extended (CLAVR-x) system runs within NESDIS and provides information on cloud detection, cloud thermodynamic type, cloud height, cloud opacity and cloud particle size. These products are made at the native AVHRR resolution (1 or 4 km) and are also produced on a global map with a resolution of 55 km. The cloud products from AVHRR have been demonstrated to be consistent with those from more advanced imagers such as MODIS. The AVHRR cloud products are used to verify NWP cloud parameterizations and the AVHRR cloud detection results are used by AVHRR applications that require cloud-free data.

Given its long record (1981-2006) and uniform set of observations, the AVHRR provides a unique data-set for satellite climate studies. In recognition of this, STAR has embarked on a project to generate a new cloud climatology from the AVHRR. The AVHRR Pathfinder Atmospheres Extended (PATMOS-x) is the successor to the PATMOS project. Unlike PATMOS, PATMOS-x will provide a full suite of cloud properties and include data from the AVHRR in the morning orbits and include data from the NOAA-klm satellites. Similar to PATMOS, PATMOS-x will also provide non-cloud products such as aerosol optical thickness and outgoing long wave radiation. This data is being used to study the multi-decal climate variability in the atmospheric parameters within PATMOS-x. The goal of PATMOS-x is to complement the view of clouds provided by other satellite cloud climatologies.

Aerosols. STAR scientists are conducting research that aims at combining historical, current and future satellite-derived aerosol optical depth (AOD) data for identification of possible trends and fingerprints of human influence. The historic AOD data are those derived from AVHRR at NESDIS and are available for the past twenty years. More recent aerosol data are available from the multi-channel MODIS instrument on the current NASA Earth Observing System (EOS) satellites (Terra and Aqua). These aerosol data are retrieved using approaches that are significantly different from the one used operationally at NESDIS. Aerosol properties in NPOESS will be derived from an instrument similar to MODIS and the retrieval will use an algorithm similar to that used with MODIS. In order to infer possible long-term trends and characterize seasonal and interannual variations the new aerosol data sets must be merged with the historic AVHHR record. To facilitate such merging the aerosol data in the Clouds

and the Earth's Radiant Energy System (CERES), Single Satellite Footprint (SSF) data set are being analyzed. The latter data set includes aerosol optical thicknesses obtained by the NASA MODIS algorithm and those retrieved by the NESDIS single-channel retrieval algorithm applied to MODIS/SSF radiances. The analysis has shown that the multi-channel and single-channel retrievals correlate well and yield similar global AOD values when both are available. In both products, a correlation is observed between the retrieved aerosol parameters and ambient cloud amount. The agreement between the two products improves when cloud and surface effects are minimized.

The differences between multi-channel and single-channel aerosol retrievals are also being investigated by applying the NESDIS single-channel aerosol algorithm to the 10-km MODIS reflectances in the MODIS Atmosphere Parameters Subset Statistics (MAPSS) data set, and by comparing the retrieved aerosol optical thickness with those from the MODIS algorithm. This provides a more direct comparison of the two aerosol algorithms over ocean since in this case the radiances used in both algorithms are exactly the same. We find that the single-channel AOD retrievals at the longer wavelength channel are similar to the multi-channel AODs, while the single-channel AODs tend to be larger then the multi-channel ones at the shorter wavelength. The difference seems to depend on the scattering angle.

STAR scientists are participating in the Aerosol Working Group (AWG) of the Global Energy and Water Cycle Experiment (GEWEX) Radiation Panel. One of the goals of AWG is to study various long-term global aerosol products for identifying and quantifying possible trends. So far, five such data sets have been compiled (three from AVHRR, one from Total Ozone Mapping Spectrometer [TOMS], and one from ISCCP-D1 data), and a preliminary comparison of them was conducted.

Aerosol optical depth data are also produced at NESDIS from the geostationary satellites and they are available in the now operational GOES Aerosol and Smoke Product (GASP). Currently, GASP is mainly used for monitoring air quality. The users include universities, and other government agencies (NASA and EPA). GASP supported the New England Air Quality Study (NEAQS) Field Campaign in July 2004. GASP has been updated to use radiances from GOES-12. An extensive evaluation and improvement of GASP is currently underway. Algorithms for aerosol retrieval from the Advanced Baseline Imager (ABI) onboard the future GOES-R satellite are also being developed. The algorithm builds on heritages from the current GOES and MODIS algorithms. Current activities include establishing the relationship between visible and near-infrared surface albedos using atmospherically corrected hyperspectral (Hyperion) observations, and adaptation of time and space dependent aerosol models to supply information needed for a successful retrieval.

Long-term Monitoring of NOAA-15 Advanced Microwave Sounding Unit-A (AMSU-A) Performance. Since the launch of the NOAA-15 satellite, the AMSU-A level 1B data have been captured from the Central Environmental Satellite Computer System (CEMSCS) and stored on optical disks. These data are used for off-line characterization of the instrument radiometric performance on orbit. Over 20 important radiometric parameters are extracted or calculated from the AMSU-A 1B data. NESDIS has already demonstrated that the noise in the observations in all channels is lower (better) than that required by the specifications and, in some channels, it is lower than estimates based on pre-launch test results. NOAA will continue compiling long-term trends of all the parameters to provide a better understanding of the instrument performance. The PC-based software developed for evaluating these data will be improved for better efficiency in processing the data.

Calibration of the Visible and Near-Infrared Channels of the AVHRR. It is very important to characterize and document the in-orbit performance of the AVHRR flown on the polar orbiters. Toward this end, a very comprehensive program of post-launch calibration and characterization of the AVHRR has been implemented to ensure the accuracy, continuity, and viability of the various AVHRR-derived geophysical products, with particular attention paid to the visible and near-infrared channels which do not have any onboard calibration devices. The major program elements are:

•Development of an optimal vicarious post-launch calibration technique, utilizing radiometrically stable calibration sites, model simulations of the radiation measured by the sensors, and simultaneous radiation measurements by the AVHRR and by calibrated spectrometers onboard aircraft;

• Enhancement of available vicarious calibration techniques to improve attainable radiometric calibration accuracies beyond ±5 percent;

• Evaluation of the feasibility of using the International Space Station (ISS) as a platform to calibrate satellite sensors, in general, using radiometers on the ISS traceable to the National Institute of Standards and Technology (NIST);

• Establishment of the AVHRR as a traveling calibration standard to monitor the performance of sensors, such as the imager on the GOES, the visible channel of the HIRS, the Moderate-resolution Imaging Spectrometer (MODIS), and various sensors to be flown on ENVISAT; and

• Design of optimal onboard and vicarious calibration techniques for the

visible and near-infrared sensors planned under NPOESS.

The relevance and importance of these activities has been recognized by the national and international user community, as evidenced by the appreciation and endorsement of the Working Group on Calibration and Validation (WGCV) and the Global Observing Systems Space Panel (GOSSP).

To ensure global access to the results of the AVHRR calibration program, and recognizing the importance of the AVHRR-derived products to national and international programs, such as the International Satellite Cloud Climatology Project (ISCCP), the International Geosphere Biosphere Programme (IGBP), the Global Climate, Ocean, and Terrestrial Observing Systems, and to benefit from sensor calibration research elsewhere, active liaison, and collaboration in some instances, has been established with researchers in NASA, NIST, EUMETSAT, China Meteorological Administration, Beijing, China; Rutherford Appleton Laboratory, United Kingdom; National Space Development Agency, Japan; the NOAA/NASA Pathfinder Program; several space agencies and remote sensing laboratories outside the US, and academia both in the U.S. and abroad.

Calibration of Geostationary Operational Environmental Satellite Instruments. The GOES ground-system calibration processing was modified to accommodate the changes in spectral locations and field-of-view sizes of the Imager channels that became effective with GOES-12. Additional processing changes are being developed to accommodate the further changes that will be made to the Imager on GOES-N. The most notable of these is a tenfold increase in the time the Imager spends viewing its blackbody for calibrating its infrared channels. The increase is intended to improve calibration precision.

On November 24, 2003, the operational calibration processing in the GOES Imager's infrared channels was modified to deal with artificial depressions in measured brightness temperatures that occurred in the hours near local midnight. These depressions, reaching a maximum of approximately 1K (for a scene at 300 K), were most pronounced in the infrared channels at the shortest wavelengths. We believe they were caused by effects of solar heating in the calibration measurements. The processing modification, which invokes a statistical technique to calculate the calibration coefficients near midnight, succeeded in minimizing the artificial brightness-temperature depressions. In addition to calibration, the product processing algorithms for several products will have been modified to accommodate the new channel configuration.

FY 2004 saw considerable progress in the on-orbit calibration of the Imager's visible channel. This channel, lacking an on-board calibration device, can only be calibrated vicariously, i.e., with targets external to the satellite. Here we report results from two such targets. From eight years of observations of a stable Earth target (the Grand Desert in Sonora, Mexico), we estimated that the responsivity of the GOES-8 Imager's visible channel degraded an average of 5.8 percent per year. From routine observations of approximately 60 stars, we estimated visible-channel responsivity degradation of 4.86 0.08 percent for the GOES-8 Imager (from 10/19/95 to 4/1/03) and 5.56 0.18 percent for the GOES-10 Imager (from 1/4/01 to 11/6/03). The difference between the GOES-8 degradation rates from the two methods is a topic of current research.

More information on GOES calibration topics, including the GOES-12 Imager channel changes, the correction for the midnight infrared-channel calibration errors, and the star- and desert-based vicarious calibrations of the visible channel, can be viewed at http://www.oso.noaa.gov/goes/goes-calibration/index.htm

Ocean Surface Winds. Calibration and validation studies are performed by STAR for all new operational ocean surface wind data streams. Product refinement and development activities are currently underway to improve ocean wind vector retrievals in the high wind speed regime, as well as precipitation regimes, where current retrieval algorithms underestimate the wind speeds. There are several satellite-based active and passive microwave sensors planned for launch in the near future from which NOAA would have the opportunity to obtain near,real-time data streams. One of these sensors will be the first demonstration of the passive polarimetric technique, which is being relied on in the NPOESS design to meet the nation's ocean surface wind vector requirements.

High-Resolution Coastal Winds and Storm Signatures from Synthetic Aperture Radar. STAR scientists have developed techniques for deriving high resolution (1 km or less) winds from synthetic aperture radar (SAR) imagery, and are using these derived winds to study ocean surface wind signatures of coastal wind phenomena of atmospheric fronts, hurricanes, and other storms. By sensing variations in ocean surface roughness on the centimeter scale, SAR sensors can image storms, atmospheric waves (such as mountain lee waves), island and mountain wakes and vortex streets, gap flows, atmospheric fronts, and barrier jets. Application demonstrations are currently underway to provide high-resolution winds, imagery, and other SAR-derived products to operational agencies for evaluation. Demonstrations included near,real-time winds for Alaska coastal waters, and SAR-derived hurricane winds. By the year 2007, there will be as many as four wide-swath SAR satellites. If data

acquisition and sharing arrangements can be established to obtain access to SAR imagery from these new sources, frequent routine SAR coverage of U.S. coastal areas will be possible. This increased coverage will allow use of SAR-derived marine and atmospheric products for operational purposes.

Ocean Color. Several programs at STAR are involved in satellite ocean color research. The Marine Optical Buoy (MOBY) Project develops, deploys, and maintains the MOBY off of the coast of Lanai, Hawaii, to measure visible and near,infrared radiation entering and emanating from the ocean. The resulting measurements support the initialization and vicarious calibration of international and national ocean color sensors, such as the Ocean Color and Temperature Sensor, the Sea-Viewing Wide-Field-of-View Sensor, and the Moderate Resolution Imaging Spectroradiometer. The Marine Optical Characterization Experiment (MOCE), MOBY's sister project, involves the collection from ship of in-situ measurements of these and other parameters relevant to ocean color in the surrounding region. Data from both sampling platforms furnish time-series of bio-optical measurements that is employed to track sensor drift, define bio-optical relationships, validate satellite-derived products, and develop ocean color algorithms. In addition to MOBY and MOCE, programs exist at STAR to routinely evaluate the accuracy of NESDIS operational ocean color products and to develop algorithms for remotely detecting and predicting the presence of noxious marine biota, such as harmful algal blooms.

Coral Reef Watch. Like the rest of the world, most of the U.S. coral reef systems are threatened due to pollution, over-fishing, and thermal bleaching. This threat includes almost all of Florida and Puerto Rico reefs, nearly half of Hawaii's reefs, and an unknown, but significant, fraction of reefs in the U.S. Pacific Territories. The widely distributed and isolated locations of many coral reefs preclude normal monitoring practices. Since 1998, NESDIS has used POES satellites to monitor the thermal bleaching stress that leads to coral reef bleaching. Research into the relationship between thermal stress and bleaching resulted in operational web-based products. These include night-time only SSTs and anomalies, and the Coral Reef HotSpot anomaly product (operational in 2002), the Degree Heating Week accumulated heat stress product and Tropical Indices webpage (operational in 2003), and the Satellite Bleaching Alert e-mail system (operational in 2005). Image products have been available to users via the Internet since the program began. Starting in 2006, gridded data products in HDF and Google Earth formats are available via ftp and OPeNDAP servers. This suite of remarkably accurate tools for monitoring potential coral bleaching events has been highly acclaimed by the user community. Operational supports for these coral bleaching products are provided at NESDIS on a 24-hour, seven-day basis. In addition, the Coral Reef Watch (CRW) program provided support to NOAA's Coral Reef Conservation Program as a key player in the emerging global Coral Reef Ecosystems Integrated Observing System (CREIOS) and continues to provide support and solid scientific basis for the development of future monitoring and assessment products and/or capabilities. The Coral Reef Watch alerts proved invaluable to researchers and managers who were able to mobilize resources to assess the record-breaking 2005 Caribbean bleaching event. NOAA Coral Reef Watch is leading an international effort to fully document the extent and severity of this record-breaking event as well as its climatic context.

CoastWatch. NESDIS has responsibility for CoastWatch Program Management. This program is managed in conjunction with other NOAA Line Offices and makes satellite data products and in-situ data from NOAA environmental buoys available to Federal, state, and local marine scientists and coastal resource managers. Data from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA's polar orbiting spacecraft are collected at Wallops Island, Virginia, and at Fairbanks, Alaska. These data are processed on NOAA computers in Suitland, Maryland, using a set of NOAA-developed multi-channel atmospherically corrected algorithms for determination of sea surface temperature. Data are then mapped (Mercator Projection) and sectored to predefined coordinates specified for each of the CoastWatch regions. Digital, high-resolution data products (1 km/4 km in a CoastWatch Binary Format) are then passed daily to CoastWatch Regional Nodes in the eastern U.S. (i.e., Southeast, Great Lakes, Northeast, Gulf of Mexico, and Caribbean). For Regional Nodes in the Pacific region, CoastWatch local data acquisition and processing capabilities are in La Jolla, California; Anchorage, Alaska; and Honolulu, Hawaii. The Internet is used as the primary telecommunications pathway for digital data distribution. Once products are delivered to the CoastWatch Regional Nodes they become immediately available for local use. An ever-growing number of Federal, state, and local organizations are establishing a formal relationship with local CoastWatch Regional Nodes for routine timely access to CoastWatch image products. More information about CoastWatch is available on the Internet at coastwatch.noaa.gov/ COASTWATCH/.

Finally, The Coast Watch AVHRR products are have undergone a modernization effort. These products are now in a new format (HDF) and use new processing software which has

improved the Earth locations of the products. CoastWatch has recently expanded, making available ocean color and ocean surface winds, as well as microwave sea-surface temperature, data and products.

NOAA NATIONAL DATA CENTERS (NNDC)

NESDIS is responsible for the management of the NOAA National Data Centers (NNDC). The NNDCs consist of three data centers: the National Climatic Data Center (NCDC) located in Asheville, North Carolina, the National Geophysical Data Center (NGDC) located in Boulder, Colorado, and the National Oceanographic Data Center (NODC) located in Silver Spring, Maryland (www.nndc.noaa.gov).

The NNDCs were established to be the Nation's primary repository for NOAA data. Since their inception, the role of the NNDCs has expanded in response to the introduction of new technologies useful to the NNDCs and available to the users. Originally designed to archive only NOAA data, the NNDCs now hold environmental data from a variety of sources, to include other U.S. government agencies, such as Department of Defense (DOD) and NASA, foreign governments, universities and cooperatives, and numerous commercial research programs.

The three NNDCs are responsible for the scientific stewardship of the Nation's environmental data and the development and operation of the associated ingest, monitoring, quality control processing, access, archive, analysis and assessment, creation of climate data records (CDRs), and other product generation systems in support of their national and international commitments and users. The NNDCs archive and provide access to numerous types of data. Each type of data provides a unique perspective for use in climate, oceanographic, space weather, and other geophysical research. It is often the combination of many of these data sets that lead to new discoveries and products that support activities, such as weather forecasting, risk (hazards-public safety and economic) mitigation, weather impact assessments, and climate assessments and predictions.

Data sets are typically divided into the method of collection: Remote (Satellites), Airborne, and in-situ (surface: land and ocean). In-situ includes radar, radiosonde, manual and automated surface observing systems, fixed and drifting buoys, etc. Observational data must be accompanied by comprehensive and complete station history data, referred to as metadata, as well as other ancillary and auxiliary documentation describing the data processing procedures (quality control and assurance) used prior to and after archiving the data.

Climate monitoring, evaluation, and prediction are critical to economic sustainability and environmental stewardship. The challenge facing the NNDCs is not only ingesting and processing very large volumes of new data, but also the convenient and timely access to the data and information. Millions of paper pages and thousands of feet of microfilm/microfiche of recorded instrument measurements and other information dating back hundreds of years are currently under the stewardship of the NNDCs. Over the past 50 plus years, many observations have been stored in digital form. There is now in place a program to convert analog records to digital form. The process will take many years to complete.

The development of a new generation of satellites over the next ten years (NASA's Earth Observing System [EOS], the next generation GOES, and NPOESS), the Initial Joint Polar System (IJPS)/Metop, and the enhancement of the operational Next Generation weather Radars (NEXRAD) (dual polarization) present major data management (stewardship and customer access) challenges to the NNDCs.

To meet these challenges, NESDIS has developed the Comprehensive Large Array-data Stewardship System (CLASS) program that will provide a significant portion, but not all, of the funding resources required to improve and maintain the information technology (IT) infrastructure required to support the mandated scientific data stewardship responsibilities for these incredibly large volumes of data.

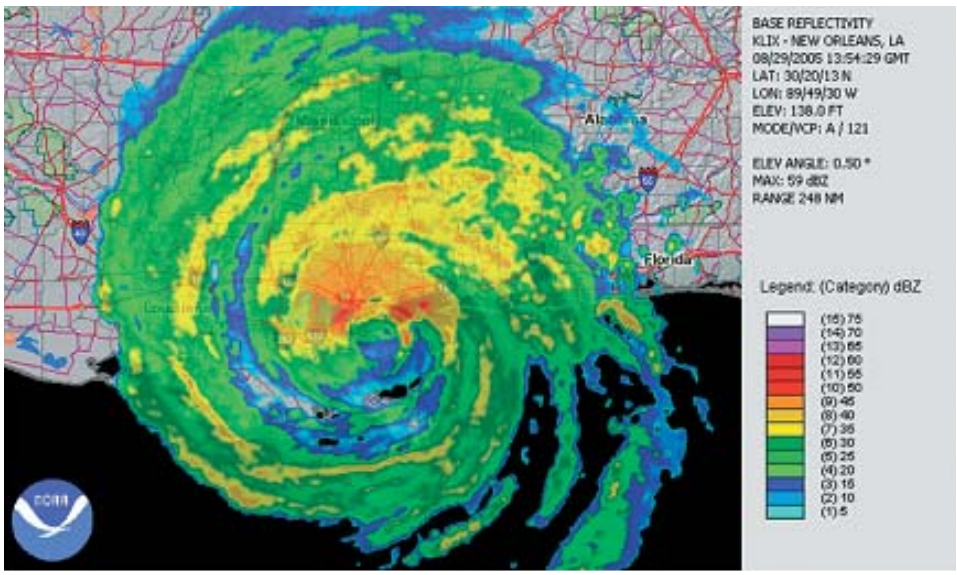


Figure 3-DOC-18. The last Hurricane Katrina image from the New Orleans radar before it lost power.

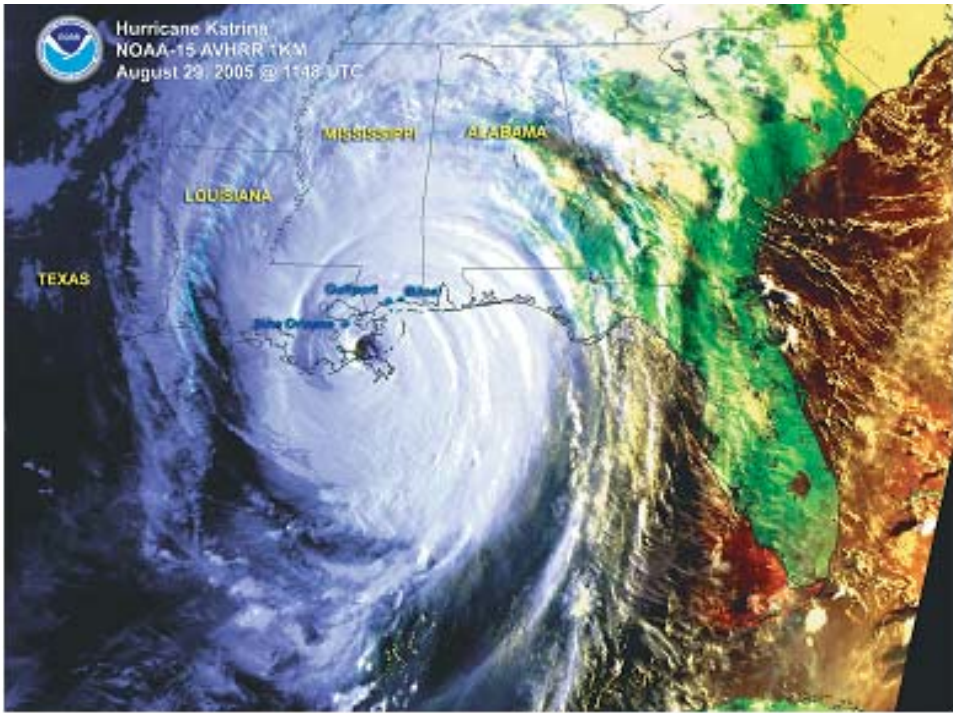


Figure 3-DOC-19. Katrina was one of the strongest storms to impact the coast of the U.S. during the past 100 years.

NATIONAL CLIMATIC DATA CENTER (NCDC)

The National Climatic Data Center (NCDC) is a designated Federal Records Center. It is the officially designated national archive for weather and climate data and information and is the world's largest archive of climate data. NCDC produces and maintains numerous data sets, products, and assessments and services many thousands of customers with data and products worldwide. In addition, NCDC operates World Data Centers for both meteorology and paleoclimatology.

National and global data sets and assessments are produced that support economic and environmental decisions and plans affected by climate variations and change. NCDC describes the climate of the U.S. through monthly and annual State of the Climate reports. NCDC is collocated with the U.S. Air Force Combat Climatology Center and the U.S. Navy Fleet Numerical Oceanography and Meteorology Detachment. These three organizations make up the Federal Climate Complex, fulfilling much of the Nation's climatological requests.

The Vision of the NCDC is: *To be the most comprehensive and accessible source of quality climate and weather related data and information services and to be an objective authority on climate monitoring.*

The Mission of the NCDC is: *To provide stewardship and access to the Nation's resource of global climate and weather related data and information, and assess and monitor climate variation and change.*

The basic functions performed by the NCDC necessary to achieve the mission include: Acquisition (ingesting observations and data) and Quality Assurance Processing, providing Access for new and historical (archived) data, Archiving data and information (long-term data stewardship), and Assessments (climate monitoring).

NCDC is the Nation's "Scorekeeper" in terms of addressing severe weather events in their historical perspective. As part of its responsibility for monitoring and assessing the climate, NCDC tracks and evaluates climate events in the U.S. and globally that have significant economic and societal impacts. Events include drought, hurricanes, tornados, severe storms, flooding, and wildfires.

NCDC is frequently called upon to provide summaries of global and U.S. temperature and precipitation trends, extremes, and comparisons in their historical perspective. Numerous web

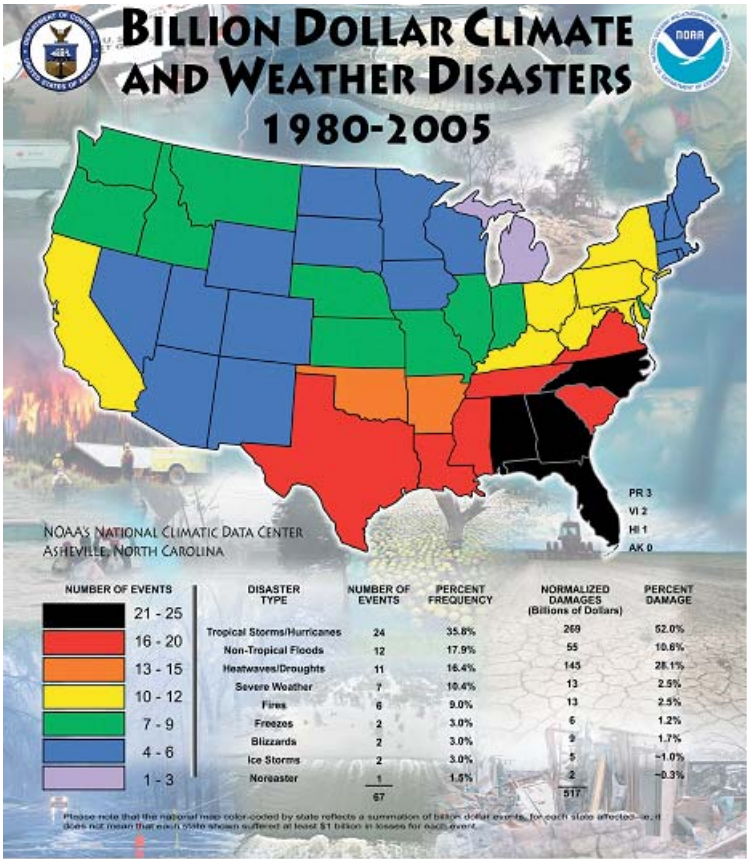


Figure 3-DOC-20. Billion Dollar Climate and Weather Disasters 1980-2005

pages and reports are available dealing with these events and with the state of the climate in general. (See http://www.ncdc.noaa.gov/extremes.html and http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html).

The U.S. sustained 67 weather-related disasters during the 1980-2005 period in which overall damages and costs reached or exceeded $1 billion at the time of the event. These disasters do not include any events that had unadjusted damages/losses less than $1 billion dollars, but subsequently may have reached $1 billion after applying the Gross National Product (GNP) inflation/wealth index. Fifty-eight of these disasters occurred since 1988, with total unadjusted damages/costs of nearly $380 billion. Seven events occurred in 1998 alone, the most for any year in the summary period, though other years have recorded higher damage totals. (See http://www.ncdc.noaa.gov/oa/reports/billionz.html).

The NCDC developed visualization tools that are used with NEXRAD level II data and NEXRAD level III products. The NCDC NEXRAD Interactive Viewer and Data Exporter load NEXRAD volume scan data and derived products into an OPEN GIS compliant environment. The applications are launched via Java Web Start and run on the client machine while accessing the data remotely from the archive at the NCDC. The NEXRAD Interactive Viewer provides tools for custom data overlays, animations, and basic queries. The export of images and movies is provided in multiple formats. The NEXRAD Data Exporter allows for data export in both vector polygon (Shapefile, GML, Well-Known Text) and raster (GeoTIFF, ESRI Grid, HDF, NetCDF, GrADS) formats. The visualization tools are now part of university course curriculums, have assisted in Space Shuttle upper atmospheric electron distribution studies, are used by the National Transportation Safety Board aircraft accident investigations, are routinely used by government and university researchers, and are being used by other countries.

Operational Programs.

The NCDC operational programs include:

• Long-term stewardship (archive and access) of the Nation's weather and climate data, as part of the Federal Records Retention System. The NCDC is an approved Agency Records Center and operates under the National Archives and Records Administration Federal Records Center guidelines and policies for managing weather and climate data records and information.

• Scientific Data Stewardship functions inherent to the mission of the legislatively designated Nation's Climate Data Center. These include developing and operating the associated ingest, monitoring, quality assessment processing, access, archive, analysis and assessment, creation of climate data records, and other product generation systems in support of national and international commitments.

• National partnerships with Federal agencies (such as the National Aeronautics and Space Administration, Department of Defense, Environmental Protection Agency, Department of Agriculture, Department of Energy, Department of State, National Science Foundation, U.S. Geological Survey, U.S. Global Climate Research Panel), many state agencies, all NOAA Line Offices, Regional Climate Centers, State Climatologists, universities, and many others. These partnerships contribute to the collection, quality assurance processing, and access to regional and national observing networks, to climate monitoring, to the national climate assessments, and to a National Climate Services Program.

• International partnerships with the World Meteorological Organization, International Council of Scientific Unions, World Data Centers, Intergovernmental Panel on Climate Change, UNESCO, and other nations through bilateral and multilateral agreements. Examples are the World Data Center for Meteorology (archiving the data collected by internationally sponsored research programs and actively exchanging climate data with foreign countries to support research and other activities) and the World Data Center for Paleoclimatology (assembling, archiving, and providing access to global paleoclimatic data derived from worldwide tree-rings, stalactites and stalagmites, coral samples, pollen and macro-fossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources).

• Maintaining and updating national and global baseline data sets and climate data records that are used for monitoring, evaluation, analyses, and assessments of climate variation and change on global and regional scales. Examples of these data sets include the Global Historical Climatology Network, the U.S. Historical Climatology Network, the U.S. Climate Reference Network, the Comprehensive Ocean-Atmosphere Data Set, the Comprehensive Aerological Reference Data Set, and the Monthly Climate Data of the World.

• Customer Service. Customers can access data, information, and products through a variety of means, such as real-time and near,real-time digital access and retrieval of new and archived historical observations through E-Commerce web enabled capabilities (Internet), as well as through traditional methods, i.e., telephone, e-mail, , facsimile, and traditional post. Digital access, retrieval, and delivery of data on-line and in a robotic storage system via the Internet is the primary and preferred customer service capability. Data and information can also be delivered on magnetic media (tape and disk), hard copy (paper and microfilm), electronic downloads, and staged for FTP trans-

fers. Many of the NCDC assessments, peer reviewed journal articles, published papers, and conference reports are also available on-line.

• Climate Data On-line (CDO) System. The CDO system is NOAA's primary means for distributing and providing access to in-situ climate data. CDO includes both recent and historical data, useful for studies of particular weather events and for historical analysis of data for statistical and other research purposes. The general types of data currently included in the system, which continues to be populated, are surface hourly, daily, and monthly data, hourly precipitation data, and 15-minute precipitation data. As data integration efforts continue, the system will be greatly expanded to include numerous additional stations and data types. There are two methods to access climate data within CDO:

• The CDO homepage (http://cdo.ncdc.noaa.gov). This provides numerous search and retrieval mechanisms, such as by region, country, state, climate division, county, and station; for any required times series.

• The GIS interface (http://www.ncdc.noaa.gov). Click on "search by map" on the left-hand side bar. The GIS tool-set provides an array of methods to select regions and locations of interest, to overlay various layers of information, etc.

Supporting Research.

The NCDC engages in an active research program to support the operational programs.

• Scientific Data Stewardship Program. This program provides an approach to maximizing the performance, quality, and utility of climate observing systems, data, and information so that the scientific integrity and long term utility of climate records for a broad range of users will be ensured. Five fundamental principles provide the framework for this program:

• Ensure Observing System quality during the design phase and real-time monitoring of performance;

• Develop an end-to end Climate Processing System that includes the timely ingest, quality assurance processing, immediate access to new and long-term access to historical records, and the long-term safeguarding of the climate records for future generations;

• Provide basic Information Technology (IT) support;

• Document Earth System Variability through monitoring and evaluation of present, future, and past observations; and

• Enable and facilitate future research through periodic analysis and assessment of new and historical records.

• Digital Health of the Network Monitoring (Observing System Performance Indicators). The purpose of the network monitoring process is to improve the quality of new observations and the fidelity of the historical archives by providing real-time information on the health and status of NOAA's observing networks. The fully developed system will continually monitor and assess the state of these networks with the intent of providing feedback that could either lead to improvements in the network or changes in analysis techniques to account for problems in the network. Anomalies and systematic performance problems are evaluated and reported to the network manager. The outcome will be improved observing system performance and higher quality data records. In most cases, these data quality issues can be identified and corrected before the data are incorporated into the historical archives and associated databases. The COOP Observing Network, the U.S. Climate Reference Network (USCRN), the Automated Surface Observing System (ASOS), and the Global Climate Observing System Surface Network (GSN) and Global Climate Observing System Upper Air Network (GUAN) are regularly monitored and the plan is to add other networks. The USCRN program has a more rigorous operational daily monitoring system of hourly performance (see http://www.ncdc.noaa.gov/oa/hofn/global-insitu.html).

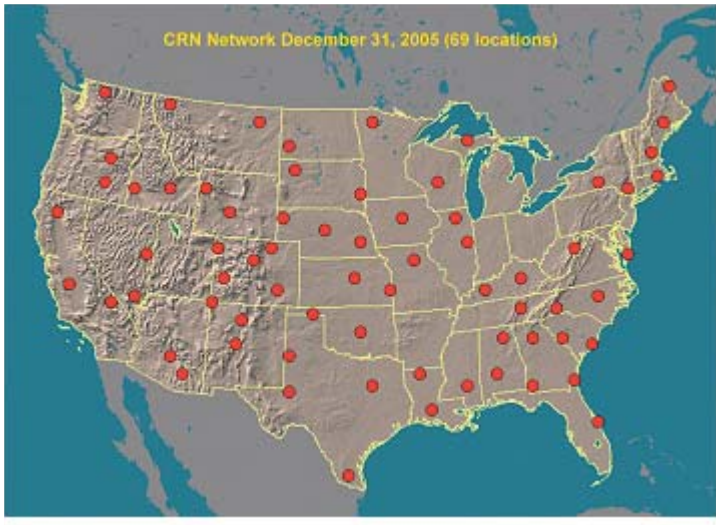


Figure 3-DOC-21. Current Climate Reference Network Site Locations

• Assessments and Reports. A series of regular reports are released regarding several key climate issues of concern to the nation. For example, the NCDC releases a monthly and annual State of the Climate for the U.S. and the North American Drought Monitoring Report which is a collaborative effort between Canada, Mexico, and the U.S. (See http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html). Continuing study of the identification and blending of key parameters from satellite, radar an in-situ observing systems will lead to a new generation of quality climate data records. Understanding and knowledge, as well as new products and serv-

Figure 3-DOC-22. USCRN Stations in FY 2008

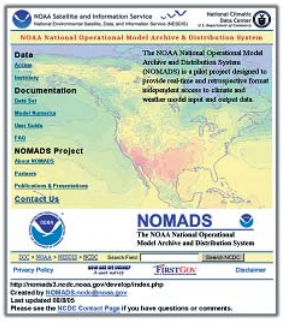
ices for research and practical economic and environmental uses, will be derived from this progressive approach to maximizing the true value of observations.

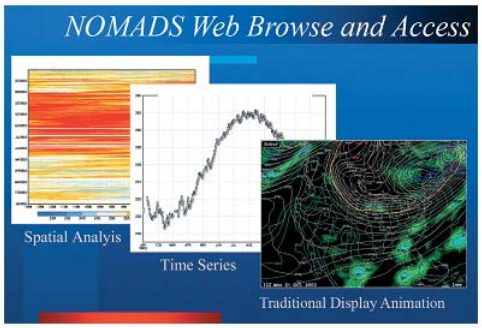
• U.S. Climate Reference Network (USCRN). The Ten Climate Monitoring Principles described in the National Research Council Report, Adequacy of Climate Observing Systems (1999), are being used to guide the design, deployment, and life cycle management of the USCRN. The USCRN is the first U.S. observing system built with the primary purpose of providing climate-quality measurements. Data from the fully deployed network of approximately 110 stations will quantify the variance in surface air temperature and precipitation on a national scale.

The USCRN climate-quality observations avoid the time-dependent biases typically experienced with other surface observing networks. The USCRN is becoming the nation's benchmark network, by providing a standard to which satellite, weather radar, and other surface systems (e.g., Automated Surface Observing System [ASOS], COOP, mesonets, etc.) observations can be validated and verified. In essence, the USCRN is providing the means to enhance the quality and confidence in other observations, as well as contribute to rehabilitating existing historical databases and data sets. This will produce a significant increase in the volume of climate quality data and information that can be used in assessing past climate trends and change, as well as contribute to the present and future climate monitoring, evaluation, and forecast tasks. (See http://www.ncdc.noaa.gov/crn.html)

• NOAA Operational Model Archive and Distribution System (NOMADS). NOMADS is a collaborative approach to provide access and data analysis capabilities for model and other data. The NCDC, in partnership with the National Centers for Environmental Prediction and the Geophysical Fluid Dynamics Laboratory, initiated this project to address a growing need for remote access to high volume Global Climate Model and Numerical Weather Prediction model data. The NOMADS team has partnered with existing and development activities including CLASS, National Oceanographic Partnership Program's, National Virtual Ocean Data System, the Department of Energy's Earth System Grid, and the Thematic Real-time Environmental Data Distributed Services developed through the National Science Foundation. NOMADS uses a distributed client-server framework of data servers together with emerging technologies to access data stored in heterogeneous formats at geographically distributed repositories. NOMADS provides, for the first time, long-term stewardship of numerical and climate model runs and provides the regional modeling community with the data necessary to initialize local models. NOMADS also provides the tools necessary to inter-compare model and observational data sets from around the world. (See http://www.ncdc.noaa.gov/oa/model/model-resources.html)

• Climate Database Modernization Program (CDMP). Digital databases of wind speed and direction, precipita-





NOAA Operational Model Archive & Distribution System provides visualization and access to model data

Figure 3-DOC-23. NOAA Operational Model Archive & Distribution System provides visualization and access to model Data.

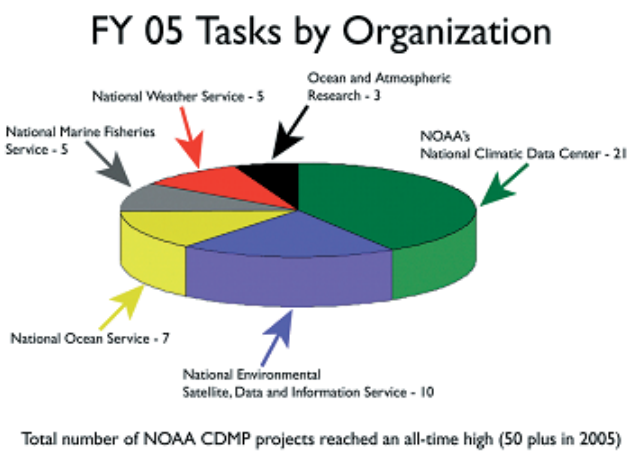


Figure 3-DOC-24. NOAA tasks supported by the Climate Database Modernization Program

tion, temperature, and pressure are far more useful than paper and microfilm records. These databases support many disciplines, including economic research, engineering, risk management, and passive (solar, wind) energy enterprises. The CDMP addresses access and utilization issues. The Program's goal is to make non-digital (paper/film) historical climate data digitally accessible and retrievable online via the Internet. The conversion of paper and microfilm records to digital databases and data sets will provide access to either optically scanned images of records or data manually keyed into digital databases. Many of these records are being merged with the more recent digital databases extending the digitally accessible and retrievable time series to many decades, as well as hundreds of years in some cases. Forty million documents have been imaged and many thousands of observations manually keyed or digitized from the merchant and military ship records, America's military forts, U.S. cities, lighthouses, weather ships, and other sources. The sixth year of the CDMP expanded into all NOAA operational line offices. The CDMP provides an unprecedented and unique opportunity to rescue valuable climate and environmental data dating back into the 1700s that are in jeopardy of permanent loss due to the deterioration of the paper and microfilm media (See http://www.ncdc.noaa.gov/oa/climate/cdmp/cdmp.html).

• NOAA Paleoclimatology Program. Paleoclimatic data is an important segment of documenting and reconstructing annual to century scale records leading to climate records dating back 10s and 100s of millennia. The incorporation of this program into the functions and activities of the NCDC enhances the identification and understanding of climate change and variation. The NCDC Paleoclimatology Branch cooperates with many countries in research projects that combine the global paleoclimate database with the instrumental record to extend the climate record back in time for climate model verification and climate change studies. Objectives of the program are to cooperate with researchers in academia, NOAA and other agencies to: conduct original research to describe the global patterns of annual-to-millennial scale climate change, understand the causes of climate change, separate man-induced climate change from natural variability, and validate the models that are used to predict future climates. (See http://www.ncdc.noaa.gov/paleo/paleo.html)

• Comprehensive Large Array-data Stewardship System (CLASS). CLASS is the NOAA implementation program for an improved architecture for archiving and servicing large-volume data. Advances in technology, including faster network access, web-based interfaces, and emerging discovery and analysis tools, will provide a one-stop capability to access the NOAA large array data sets. The CLASS objective is to establish a web-enabled browse, order, and retrieval delivery system that will enhance and increase the availability and accessibility of satellite, radar, and other data and derived products to customers worldwide. The CLASS integrated storage and web-based access and servicing system design incorporates many of the features and capabilities of the current Satellite Active Archive system built for the POES data stored on a robotic system located in Suitland, MD. The CLASS program has established dual sites, one in Asheville, NC, and another in Suitland, MD. There are plans to move the Suitland site to Boulder, CO. A third CLASS site is also slated for Fairmont, WV. NOAA Polar-orbiting Environmental Satellite (POES) and Geostationary Orbiting Environmental Satellite (GOES) data are currently available via the CLASS interface. CLASS data and product enhancements will be implemented in phases called campaigns. New major campaigns planned include NEXRAD, National Polar-orbiting Environmental Satellite System Preparatory Program (NPP), National Polar-orbiting Operational Environmental Satellite System, Earth Observing System Long Term Archive, and the European Meteorological Operational Satellite Program (see http://www.class.noaa.gov).

• Air Quality Forecasts. NCDC archives NOAA's Air Quality Fore-

casts. The Air Quality Forecasts are forecast guidance of one-hour and eight-hour averaged ground-level (surface) ozone concentration. The guidance is produced twice a day, for hourly intervals through midnight on the following day (48 model hours), seven days a week for the northeastern U.S. initially, and then gradually will include the entire U.S. by 2009. NWS provides the data. These data provide ground-level ozone forecast guidance for state and local air quality forecasters and help the public limit adverse effects from poor air quality. This forecast guidance helps meet a congressionally directed national air quality forecast capability. These data will have received a high measure of quality control through computer and manual edits.

NATIONAL OCEANOGRAPHIC DATA CENTER

The National Oceanographic Data Center (NODC) (www.nodc.noaa.gov) manages the world's largest collection of publicly available oceanographic data. NODC holdings include in-situ and remotely sensed physical, chemical, and biological oceanographic data from coastal and deep ocean areas. NODC customers reuse this data to answer questions about climate, ocean, and coastal phenomena.

NODC also operates NOAA's Central and Regional Libraries. These libraries provide environmental references services that support NOAA research and other technical information retrieval services to NOAA staff; and maintain the official archives for NOAA documents.

Internationally, NODC hosts the World Data Center for Oceanography, Silver Spring under the auspices of the International Council of Scientific Unions and the U.S. National Academy of Sciences.

NODC supports ecosystem stewardship through the National Coastal Data Development Center (NCDDC) in Stennis, Mississippi by providing access to the nation's coastal data resources. NCDDC achieves this capability through the integration of diverse coastal data distributed in multiple repositories and provides these data to users via the Internet using established and emerging technologies. They provide a searchable metadata catalog of coastal data, developing gateways to data repositories and using middleware technology that provides data in user specified formats.

Specifically, NODC data archive and access responsibilities support climate research and operational ocean observing system activities. NODC performs ocean profile data management for internationally coordinated global ocean observing systems such as the Argo Ocean Profiling Network and the Global Temperature-Salinity Profile Program (GTSPP) in cooperation with applicable JCOMM committees. NODC's objectives are

- To safeguard versions of the Argo and GTSPP near,real-time and retrospective data and information, and
- To provide high quality data to a wide variety of users in a timely and useful manner.

The Argo and GTSPP data system present an excellent opportunity to improve ocean and climate forecasting, with consequent benefits for the protection of life and property and effective planning for the effects of seasonal to inter-annual climate variability.

NODC produces regular updates of the World Ocean Database and World Ocean Atlas. The most recent version, 2001, includes over seven million profiles of scientifically quality controlled ocean temperature, salinity, oxygen, plankton, pigment, and nutrient data. The Atlas presents statistics and objectively analyzed fields for one-degree and five-degree squares generated from World Ocean Database 2001, observed and standard level flagged data. The ocean variables included in the atlas are: in-situ temperature, salinity, dissolved oxygen, apparent oxygen utilization, percent oxygen saturation, dissolved inorganic nutrients (phosphate, nitrate, and silicate), chlorophyll at standard depth levels, and plankton biomass sampled from 0 - 200 meters depth. Further information on both products is available at: www.nodc.noaa.gov/OC5/indprod.html.

The NOAA Marine Environmental Buoy Database (http://www.nodc.noaa.gov/BUOY/buoy.html) is one of the largest and most frequently used data archives maintained by the NODC. This database holds wind, wave, and other marine data collected by the NOAA National Data Buoy Center (NDBC) from moored buoys and C-MAN (Coastal-Marine Automated Network) stations. Parameters reported by both buoys and C-MAN stations include air temperature and pressure, wind speed and direction, wind gust, and sea surface temperature.

NODC is developing a capability to provide public access to consistently-processed, climate-capable satellite datasets and applying them to various scientific problems. The first products provided in 2003, were Pathfinder reprocessed 9 km and 4 km sea surface temperatures. For further information see www.nodc.noaa.gov/sog/.

The National Coastal Data Development Center (NCDDC) manages the Coastal Data Development (CDD) program. The focus of NCDDC is to improve the quality of web-based search and access tools and implement web-based access to priority data sets from Federal, state, and local repositories. Geospatial display capabilities have been added that allow the user to link the data to coastal imagery, charts, bathymetry to obtain a complete data picture of the ecosystem of interest.

To identify priority data sets, NCDDC coordinates with Federal, state, and local agencies, academic institutions, non-profit organizations

and the private sector to create a unified, long term database of coastal data sets available from a variety of sources. The NCDDC develops and maintains a catalog of available coastal data, builds gateways to these sources, ensures the equality of the metadata, populates and updates the databases, and provides on-line search and access and geospatial display for the coastal user community.

The CDD program supports NOAA's Ecosystem strategic goal which aims to build the capacity of Federal, state, local, and international managers to make decisions that protect, restore, and use coastal ecosystem services. The Earth's coastal ecosystems are home to a wealth of natural resources, and the lives and livelihoods of people are linked to these national treasures. Sustainable growth of our coastal regions is critical to our economy by supporting commercial and recreational fishing, waterborne commerce, home construction, and tourism. Base activities aim to advance understanding and predict changes in the Earth's environment to meet the economic, social, and environmental needs of the U.S.. This supports the strategic goal of the Department of Commerce to, "*Observe, protect, and manage the Earth's resources to promote environmental needs*."

NOAA/NODC Library

NODC houses the NOAA Central Library (www.lib.noaa.gov/) which supports weather and climate research programs by providing a variety of information services, including:

• Access to print and electronic versions of American Meteorological Society journals.

• Access to Meteorological and Geoastrophysical Abstracts (desktop access at the Silver Spring campus).

• Desktop access to Web of Science at several NOAA sites.

• Assistance in obtaining site licenses for 169 National Weather Service field sites for electronic access to Monthly Weather Review and Weather and Forecasting.

• Archival of historic collections of the Weather Bureau.

• Data rescue of hundreds of volumes of meteorological data publications in danger of loss.

NATIONAL GEOPHYSICAL DATA CENTER

National Geophysical Data Center (NGDC) (www.ngdc.noaa.gov) staff archive, assess, and provide access to satellite and ground-based observatory data from national and international programs supporting research in meteorology, climatology, and space weather as well as solar-terrestrial physics, snow and ice, marine geology and geophysics, and solid Earth geophysics. The National Snow and Ice Data Center (NSIDC), at the University of Colorado, is an affiliated partner with NGDC. World Data Centers for Solar-Terrestrial Physics, Marine Geology and Geophysics, Glaciology, and Solid Earth Geophysics under the auspices of the International Council of Scientific Unions are operated by the two national centers. Research activities focus on satellite remote sensing to assess the long-term changes of the land surface, the space environment, snow cover and sea ice.

Long-term archive responsibilities for the nation are provided by NGDC activities. NGDC maintains the nation's archive for global tsunami and related hazard events. This includes tsunami events, triggers, run-up locations and heights, damage descriptions and photographs. This information is essential for researchers focusing activity on at-risk areas. As part of NOAA's effort to improve tsunami research and warning, NGDC has established a long-term archive for ocean bottom pressure and Deep-ocean Assessment and Reporting of Tsunamis (DART) data. NGDC also manages the sole archive of space weather data from GOES, POES and DMSP satellites. NGDC maintains the only archive of raw data records and visible and near-infrared imagery collected on DMSP satellites for meteorological, oceanographic and Earth surface studies. The space weather ground-based archives focus on data used in NOAA's space weather forecasts, warnings and alerts. NSIDC manages cryospheric data from both ground-based and satellite instruments. These data stewardship and scientific stewardship activities for satellite and ground-based data include processing, management, analysis and quality assessments.

Online WWW-based access services to these large databases continue to evolve at NGDC. Data discovery, browsing, and delivery are fairly mature functions. Data directories are managed by relational database management systems available to most search engines. Almost all of the data sets reside in robotic libraries and are accessible online, however some data sets are easier to browse, display and use than others. NGDC uses Web map-based access to the integrated hazards databases. Users can select events either through a geo-referenced map interface or via traditional search and retrieve engine. NGDC has several projects as part of the NESDIS program to digitize and make accessible the most important records in the huge historical archive. Interactive displays of multi-disciplinary data sets and data mining are under development and NGDC has embarked on an environmental scenario generator project to mine information from the archives and to use the mined information to launch numerical simulations of the atmospheric and space environments.

The DMSP activity prepares calibrated and geo-referenced records from the raw data records recorded by the scientific instruments on DMSP satellites. Data sets include visible, infrared and microwave imagery,

microwave soundings and in-situ measurements of the space environment. User services are provided through the Space Physics Interactive Data Resource (spidr.ngdc.noaa.gov/spidr/). Research activities focus on the use of the nighttime visible and infrared imagery from the DMSP Operational Linescan System (OLS). The nighttime lights product has been used to assess changes in power consumption both regionally and globally over the period 1992 to present. Nighttime lights have been used to support humanitarian relief services after natural disasters such as Hurricanes Wilma and Katrina.

GOES, POES and DMSP satellite data of solar activity and the near Earth space environment managed by NGDC provide the long-term monitoring of space weather conditions. These data record the Earth's magnetic field, the electrically charged environment, and solar x-rays from geosynchronous and polar sun-synchronous altitudes. Data from ground-based observatories recording solar activity, ionospheric characteristics and geomagnetic variations complement, enhance and provide ground truth for the satellite measurements. The Solar Geophysical Data bulletin containing solar and space weather data is published monthly. The space weather program at NGDC archives measurements of total solar and solar spectral irradiance for use in climate studies (http://spidr.ngdc.noaa.gov/spidr/). Tabular listing of ionospheric parameters and ancient solar images are part of the digitizing and access program.

National Snow and Ice Data Center

The National Snow and Ice Data Center (NSIDC) at the University of Colorado, which is affiliated with NGDC, manages several cryospheric-related data archives of interest to meteorology and climatology. These data sets include a collection of historical photographs of glaciers, temperature, pressure and position data from drifting buoys placed on the central Arctic pack ice and data from the NOAA snow cover and DOD-NOAA sea ice chart digitizing projects. NSIDC provides data management services for a variety of cryospheric research programs sponsored by NASA and NSF. In addition, NSIDC has developed gridded sea ice products (sea ice concentrations and multi-year ice fraction) based on passive microwave data collected by NASA and DMSP satellites (see Figure 3-DOC-24). NSIDC is acquiring snow cover, glacier and sea ice records from the former Soviet Union. Online services are available at www.nsidc.colorado.edu.

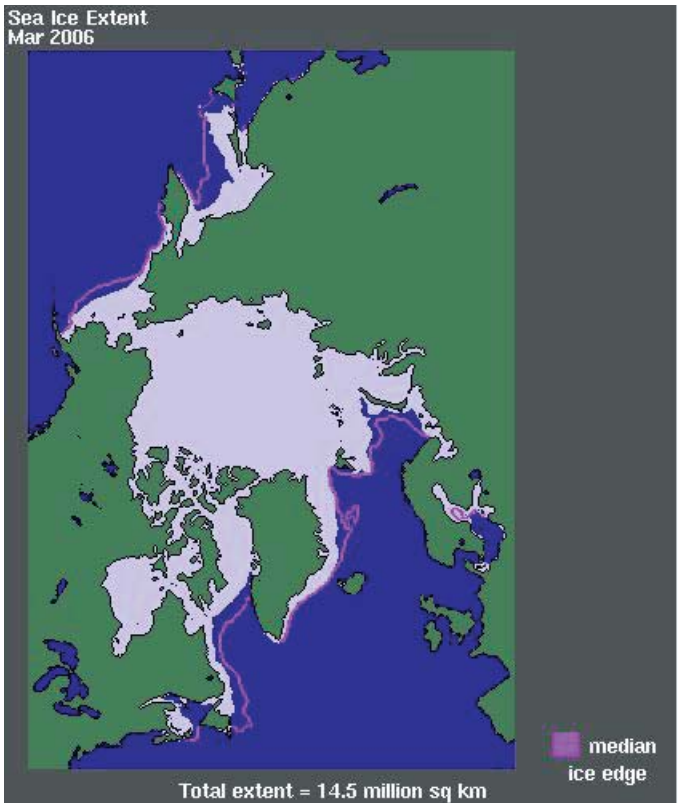


Figure 3-DOC-25. This image, from the NSIDC Sea Ice Index, shows the extent of Arctic ice in March (grey area) relative to the normal position (based on a reference period of 1979 to 2000), shown by the pink line. March is the month of greatest Arctic ice extent. While scientists have known of the decline in summertime ice extent for years, the statistically significant negative trend in winter ice extent is a new phenomenon. Scientists and the interested public can tract ice trends at nsidc.org/noaa/seaice_index/.

Supporting Research

Natural Hazards Reduction. Severe tsunami events are relatively rare and frequently the first reaction to a serious event such as the 26 December 2004, Indian Ocean tsunami is to clean-up the damage. A global database of past tsunami events, run-up heights, death and damage descriptions, and photographs is an essential research tool when identifying at risk areas and likely damage from modeled events. NGDC maintains the nation's global tsunami event database. In FY 2006 NGDC reviewed and documented 60 percent of events with the global tsunami database classified as significant, including the locations and magnitudes of the source events, maximum runups and total effects. As an associated activity, NGDC in FY 2006 established a web-accessible archive of tsunami program Deep-ocean Assessment and Reporting of Tsunami (DART) Buoy and Bottom Pressure Recorder (BPR) historical data. These historical records provide the baseline against which real-time measurements can be compared to assess the threat posed by tsunamis (see Figure 3-DOC-25 and http://ngdc.noaa.gov/seg/hazard/DARTData.shtml)

Environmental Remote Sensing. Operational meteorological satellite systems provide a unique opportunity to monitor features on or near the Earth's surface, sometimes on a nightly basis. The DMSP nighttime imagery are used to locate sources of visible

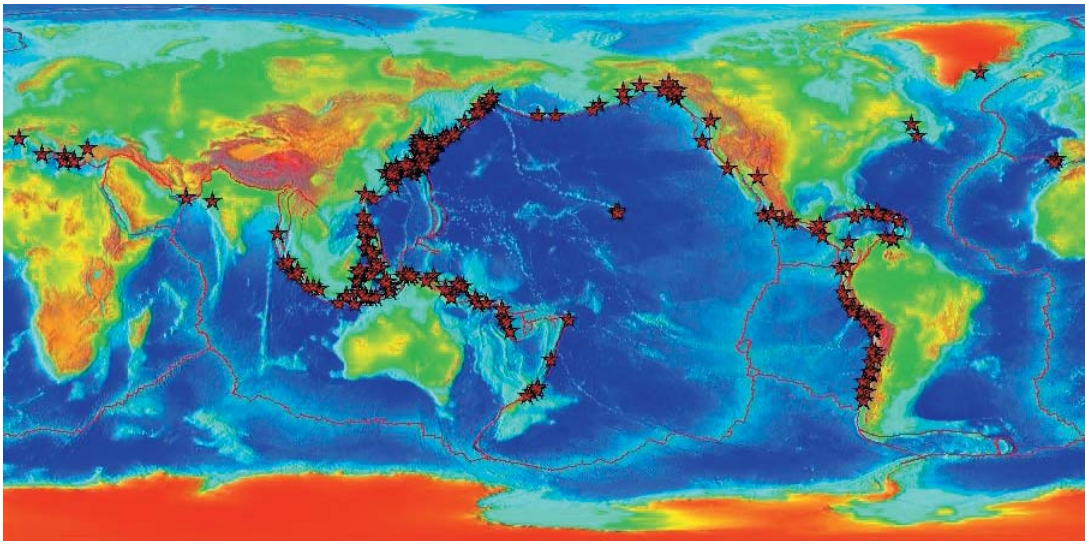


Figure 3-DOC-26. Global distribution of significant tsunami events occurring between 1410 and 2004.

and infrared emissions including city lights, lightning, wildfires, flaring gas, and fishing boats. Research projects use the city lights to infer such diverse parameters as population density, economic vitality, and carbon dioxide emissions. More information is available at dmsp. noaa.gov/ dmsp.html.

Wildfires Monitored from Space. DMSP OLS imagery offers a unique opportunity to monitor wildfires because each satellite records nighttime visible emissions covering the entire globe each day. Instruments designed to detect clouds also see wildfires--many of which burn in very remote areas. NGDC has developed a unique capability to capture the nighttime emissions from both large and small wildfires. The system has been used to assist the NOAA Operational Significant Event Imagery team and by firefighters in developing countries. More information is available at dmsp.noaa.gov/dmsp.html.

Space Weather. The Space Weather program at NGDC is dedicated to the long-term archive and analysis of NOAA's space weather data. This year marks the completion of a 15-year space weather climatology, covering the ionosphere, thermosphere and inner-magnetosphere. The project, which is designed similarly to the NCEP/NCAR re-analysis project, provides the user community with a uniform view of key space weather domains. In the coming years, analysis of this data will allow for tracking of changes observed in the near-Earth space environment (see Figure 3-DOC-26).

Cryospheric Research at NSIDC. NSIDC's research interests cover a broad spectrum of climate-cryosphere interactions using a variety of observing techniques with special emphasis on arctic regions and satellite-borne instruments. Research projects within NSIDC study the long-term record of snow and ice in polar and mountainous regions, as well as the hydrology of the southwestern US. Algorithms to detect snow, frozen ground and sea ice in passive microwave images from DMSP and NASA satellites have been developed at NSIDC.

Other research includes developing models of the physical and mechanical properties of snow and ice in glaciers and the freeze-thaw cycles of soils in polar regions (the latter is an important component of hydrological modeling). Another area of special interest and study is the interaction between sea ice and the ocean and atmosphere. More information is available at http://nsidc.org/.

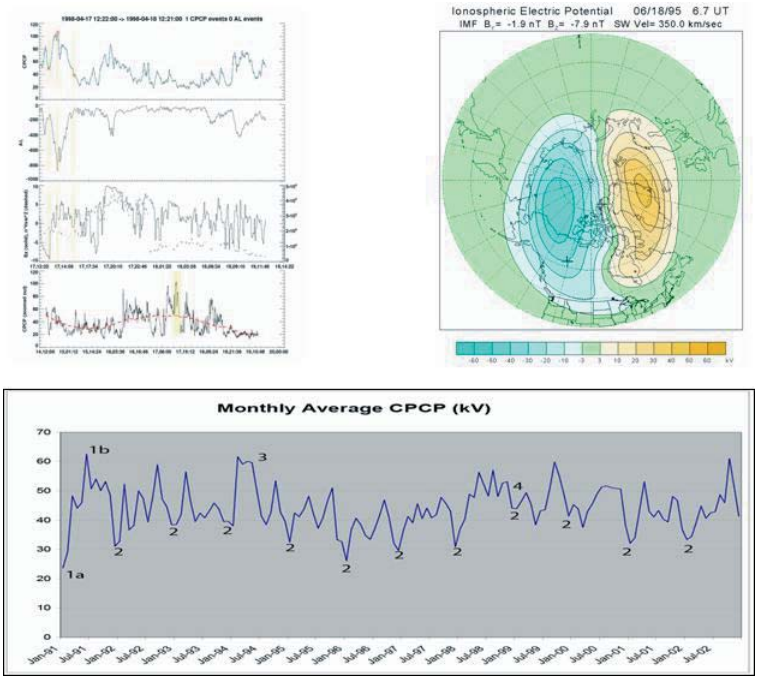


Figure 3-DOC-27. 15-year record of the near-Earth space environment obtained by coupling observational space weather data with physics-based numerical models.

Programs within the Oceanic and Atmospheric Research (OAR) Laboratories support various National Oceanic and Atmospheric Administration (NOAA) meteorological and oceanographic missions. The activities of OAR laboratories provide the innovative ideas needed to improve our understanding of atmospheric, oceanic, and climate science and develop the practical solutions, tools, and techniques that form the basis of improved ocean, weather, water, and climate services. In an effort to make OAR's meteorological, oceanographic, and climate research more extensible, OAR recently re-organized its laboratories in Boulder, Colorado. The new Earth System Research Laboratory (ESRL) consists of four Divisions: Chemical Sciences Division (CSD), Global Monitoring Division (GMD), Global Systems Division (GSD), and the Physical Sciences Division. These divisions were formed in the consolidation of the former Aeronomy Laboratory, Climate Diagnostics Center, Climate Monitoring and Diagnostics Laboratory, Forecast Systems Laboratory, and the Environmental Technology Laboratory. A portion of the former Environmental Technology Laboratory has now transferred to the University of Colorado as the Center for Environmental Technology (CET).

In an effort to improve national resiliency and better protect lives and property, OAR places special emphasis on improving severe weather, flood, and hurricane warnings and forecasts and on improving the utilization and dissemination of data and information. Severe weather events include flash floods, strong winds, thunderstorms (including tornadoes, lightning, and hail), heavy snowstorms, extreme cold and heat, drought, and geomagnetic storms. OAR also places emphasis on enhancing our understanding of the global climate system and improving regional decision support tools for climate and weather.

Key contributions to improved hurricane forecasts fall under the "Hurricanes at Landfall" (HL) focus of the U.S. Weather Research Program (USWRP), the funding for which resides in NOAA's National Weather Service (NWS), and the implementation of which is in OAR. They include more accurate prediction of track, intensity, surface winds, rainfall, improved communication of hurricane forecast information, and improved understanding of human impacts. Improving flood forecasts fall under the component of USWRP labeled "Improving Quantitative Precipitation Forecasting." In pursuit of improved utilization and dissemination of data, the OAR laboratories conduct both in-house and cooperative research with other NOAA organizations, government agencies, joint institutes, universities, and the private sector. In addition, OAR laboratories conduct research to improve routine weather forecasts and improve the ability to forecast regional air quality and atmospheric deposition.

A significant focus of OAR in the weather and air quality area is the development of operational testbeds under the auspices of the USWRP. These testbeds are the mechanism through which research is transitioned to operations. It is recognized by the USWRP that since NOAA is one of the forecast mission agencies in the program, and the program goals are predominantly operational ones, its most significant role in the USWRP is to provide the infrastructure and capabilities to efficiently and effectively test research products in an operational environment. The testbeds are the Joint Hurricane Testbed, the Developmental Test Center (http://www.dtcenter.org/), and the Joint Center for Satellite Data Assimilation (http://www.jcsda.noaa.gov/). These testbeds are operated in partnership with other USWRP agencies. OAR's role is to provide directed research and operational testing, in partnership with the NWS. In addition, the Weather Research and Forecasting (WRF) community model (http://www.wrf-model.org/index.php), also under the auspices of the USWRP, provides a common modeling structure to be shared by most of the testbeds and between the research and operations communities. Several OAR laboratories are involved in the WRF development in partnership with the NWS and other USWRP agencies.

In 2004, the USWRP established the Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information or Societal Impacts Program (SIP) for short (http://www.sip.ucar.edu/). Its mission is to be a clearing house for socioeconomic information on weather, to increase knowledge among the weather community concerning the human and economic impacts of weather, to better determine the value of weather information, and to improve our ability to communicate weather information to all public and private sectors. Within the SIP is a Hurricane Working Group, consisting of the top social scientists, economists, and meteorologists in the U.S. who have worked in the area of hurricanes. They have developed an agenda for

social science research for hurricane forecasts and warnings (http://www.sip.ucar.edu/hurricane.jsp).

In 2004, the World Meteorological Organization established THORPEX: A Global Atmospheric Research Program (http:// www.mmm.ucar.edu /uswrp/programs/nathorpex.html, from which one can link to the international THORPEX website). Currently twelve countries are participating. In the U.S., NOAA is the lead agency and participating agencies include NASA, NSF, and the Navy. THORPEX is a 10-year international global numerical weather prediction program to accelerate improvements in one to 14-day forecasts of high impact weather. In NOAA, OAR, NWS, and NESDIS participate in THORPEX with the Joint Center for Satellite Data Assimilation as a key component. In NOAA, the THORPEX program is developing global ensembles of model predictions and ensembles of ensembles such as the North America Ensemble Forecasting System (NAEFS) in collaboration with Canada and Mexico, which is now being operationally tested at NWS's National Centers for Environmental Prediction's Environmental Modeling Center. The THORPEX funding in NOAA resides in the NWS and is administered by OAR.

OBSERVING TECHNOLOGY

Meteorological, oceanographic, and climate research requires a strong network of observing systems providing data and information and consistent advancements to our observational capabilities. In support of NOAA's mission, OAR supports the advancement of our observing technology through the development and testing of new observing systems, observation techniques, and data ingest and dissemination systems. All OAR observing technology research supports the Global Earth Observing System of Systems (GEOSS) and further establishes OAR as a preeminent leader in meteorological, oceanographic, and climate research.

Numerous OAR laboratories and their related academic and private sector partners are heavily involved in developing new environmental observing system technologies. The Global Systems Division (GSD) of the Earth System Research Laboratory (ESRL) in Boulder, Colorado, takes promising new scientific and engineering technologies from the research arena, helps develop them into mature engineering systems, and transfers these technologies to NOAA operations and the private sector. The Physical Sciences Division (PSD) of ESRL applies and evaluates new remote-sensing concepts and systems. The National Severe Storms Laboratory (NSSL) in Norman, Oklahoma, both develops new remote sensing systems and assists in the transfer of these technologies to the NWS. The Atlantic Oceanographic and Meteorological Laboratory (AOML) in Key Biscayne, Florida, develops, deploys, and manages in-situ oceanographic observing systems across the global oceans. This environmental research, development and associated transition of products and services directly support the Nation's forecasting and warning services.

GSD is investigating the use of superpressure balloons in the stratosphere as a platform for monitoring and observing the environment. Among the balloons' capabilities would be atmospheric soundings. The trajectory of the balloons could be controlled to some extent by adjusting their altitude so as to take advantage of the vertical shear. The balloons would carry compact, lightweight sondes whose locations could be tracked as they fell toward the surface. The balloons would comprise a moderately priced global system.

A number of engineering tests have already been performed at altitude by piggybacking on a zero-pressure balloon launched by the Physical Science Laboratory at New Mexico State University and with launches near the Oregon coast. Telemetry was received line-of-sight from a distance of over 200 miles, the storage batteries were charged by solar panels, the proper thermal environment was maintained during the daytime heating cycle, and the instrument package was successfully recovered after descent by parachute.

GSD is also taking a leadership role in implementing the International Earth Observation System includes the development and testing of Unmanned Aircraft Systems (UAS, formerly referred to as UAVs) for providing global weather and climate observations. The GSD is one of several NOAA Research laboratories collaborating with NASA in support of this project. The goal of these missions is to evaluate the utilization of UASs for improved U.S. and global observing. The Altair's integrated sensor package consists of such components as an ocean color sensor and passive microwave sounder developed by the NOAA's PSD, a gas chromatograph and ozone sensor developed by GMD, a digital camera system provided by NASA, and an electro optical infrared sensor provided by GA-ASI. High and medium altitude, long-duration UASs can fly at remote locations in dangerous flying conditions for long periods. This technology provides many scientific benefits such as sustained global high quality all-weather profiles of atmospheric composition (water vapor,

Figure 3-DOC-28. Altair UAS.

aerosol, cloud water and trace gases), and high altitude vertical resolution and profiling. It also offers a rapid response platform for improved high impact weather forecasts at 1-day to 2-week lead times, and better climate change detection, attribution, and prediction in support of policy decisions.

PSD and GSD will continue development of new sensors and innovative techniques for combining observing systems synergistically and economically. Efforts include developing tools and techniques to integrate the data from surface-based and satellite-borne profiling systems for more effective use of these data in forecasts. In support of this effort, PSD has an active satellite remote sensing group that uses data from various environmental satellites to study air-sea interaction processes, the global hydrological cycle including water vapor and precipitation, and the Earth's radiation budget.

Icing is a weather hazard that occasionally causes aviation disasters, especially in winter. In-flight icing forms on wings and other exposed surfaces as an aircraft flies through clouds that contain super-cooled liquid water droplets. Leveraging earlier work with polarization-sensitive cloud radars, PSD designed a new ground-based cloud radar and radiometer system to monitor clouds in the vicinity of airports and to provide automated warnings of icing conditions aloft. This instrument is the Ground-based Remote Icing Detection System (GRIDS). In addition, GSD continues to perform research and analysis to improve aviation forecasts.

PSD, in association with the Center for Environmental Technology (CET) at the University of Colorado is developing an airborne Polarimetric Scanning Radiometer (PSR) designed to provide higher resolution measurements of sea state quantities, including surface winds. PSD/CET is also investigating the possibility of measuring soil moisture by L-band radiometers.

Starting in 2003, PSD and GMD have been working together with the Canadian Meteorological Service and Canadian Network for the Detection of Climate Change (CANDAC) to re-establish a new Arctic Atmospheric Observatory at Eureka, Ellesmere Island, Canada, in North East Canada as a part of the U.S. Studies of Environmental Arctic Change Program (SEARCH). The Canadian Observatory is being designed to mirror many of the cloud, aerosol and radiation measurements that are already made at the GMD Baseline Observatory in Barrow, Alaska, that has been in continuous operation for 33 years. . Since North East Canada and Barrow, Alaska are in markedly different Arctic regimes the long-term measurements from these sites will be complementary in providing information to monitor Arctic atmospheric changes. Long-term data from these sites will be used to improve short-term and long-term forecast models, and improve satellite measurement of meteorological phenomena in the Arctic regions. Along with the National Science Foundation, PSD and GMD are helping to refurbish a historic meteorological station and establish an Atmospheric Baseline Observatory at Tiksi, in the Russian Arctic. This would be the first station of this type in a region that spans 75 percent of the Arctic littoral. Meteorological data from this newly re-instrumented site will continue a century of data collection that had deteriorated since the collapse of the Soviet Union, and expand measurements to complement those collected at Barrow, Alaska and Eureka, Canada. The high quality of the data to be soon forthcoming from the Tiksi station should considerably enhance Arctic weather prediction and Arctic climate models.

PSD is engaging in a comprehensive observation program to improve operational weather forecast and planned climate model treatments of boundary layer forcing processes. This work centers on development and application of observing technologies for surface fluxes and key boundary-layer variables (profiles of temperature, humidity, wind, and cloud properties). Ship-based measurement systems have been developed and are now used routinely on NOAA research vessels to investigate model accuracies in the marine boundary layer. Recently, land-based systems have been developed and deployed. One point of emphasis is linking observed cloud properties (obtained with mm-wavelength cloud radars and microwave radiometers) to cloud effects on surface turbulent and radiative fluxes (this approach is termed cloud forcing). Ship-based and satellite retrievals of cloud and flux properties are being used. PSD is compiling a large data base to allow climatologically-oriented studies of model parameterizations. Future plans include expanding the observational capabilities to add scanning mm-radar capabilities for investigation of precipitation initiation (a critical issue in triggering deep convection in model domains).

The PSD satellite applications group has developed new techniques for monitoring atmospheric properties over the ocean surface including air temperature and specific humidity. Retrievals of these quantities were improved through a novel use of satellite atmospheric sounders in combination with passive microwave imaging radiometers. The products are being applied to improved global estimates of the flux of heat between the ocean and atmosphere. PSD is also producing a new satellite-derived sea surface temperature product through the blending of infrared and passive microwave data. The technique takes advantage of the complementary strengths of the two sensor types. The product has significant meteorological applications through its use as an input to numerical weather forecast and cli-

mate models.

The NSSL is known for its development of observational capability, both remote and in-situ, and in particular for its role in the development of the WSR-88D NEXRAD radar. NSSL continues to improve the WSR-88D software algorithms used by the NWS forecasters and is exploring ways to enhance the WSR-88D hardware using dual polarization techniques under the NEXRAD Product Improvement (NPI) activity. NPI planning, guidance, and funding involves NOAA, DOT/FAA, and DOD/Air Force.

Most weather radars, including the WSR-88D NEXRAD radar, transmit radio wave pulses that have a horizontal orientation. Polarimetric radars (also referred to as dual-polarization radars), however, transmit radio wave pulses that have both horizontal and vertical orientations. The horizontal pulses essentially give a measure of the horizontal dimension of cloud (cloud water and cloud ice) and precipitation (snow, ice pellets, hail, rain) particles while the vertical pulses essentially give a measure of the vertical dimension. Since the power returned to the radar is a complicated function of each particle size, shape, and ice density, this additional information results in improved estimates of rain and snow rates, better detection of large hail location in summer storms, and improved identification of rain/snow transition regions in winter storms. The signal processing requirements for dual polarization requires an initial step of deploying a new Radar Data Acquisition (RDA) unit for the WSR-88D that is capable of processing the polarimetric signals. The new RDA deployment is underway and is currently scheduled for completion of the U.S. network the week of September 25, 2006.

In 2020, the WSR-88D radars forming this NEXRAD network will be over 23 years old. In about the same time frame, most of the Nation's aircraft surveillance radars will be nearing the end of their design life. Decisions on replacing or repairing and upgrading these National radar assets must be made over the next 10 to 15 years. We are now on the threshold of a revolution in civilian radar capability, enabled by the adaptation of established military radar technology to existing civilian applications, plus new capabilities beyond what current systems can provide. Historically, civilian radars with large rotating antennas like the NEXRAD weather surveillance network and the aircraft surveillance radars used by the Federal Aviation Administration (FAA) evolved from military radar applications. During the past several decades, a new generation of military radars has matured. These electronically scanning phased array radars with no moving parts (rotating antennas) were originally developed to track multiple airborne objects such as aircraft and missiles simultaneously. The unique beam agility, increased resolution, and faster full-volume scan rate of phased array radar can enable a single radar unit to perform multiple weather and atmospheric surveillance tasks and, at the same time, track multiple airborne craft.

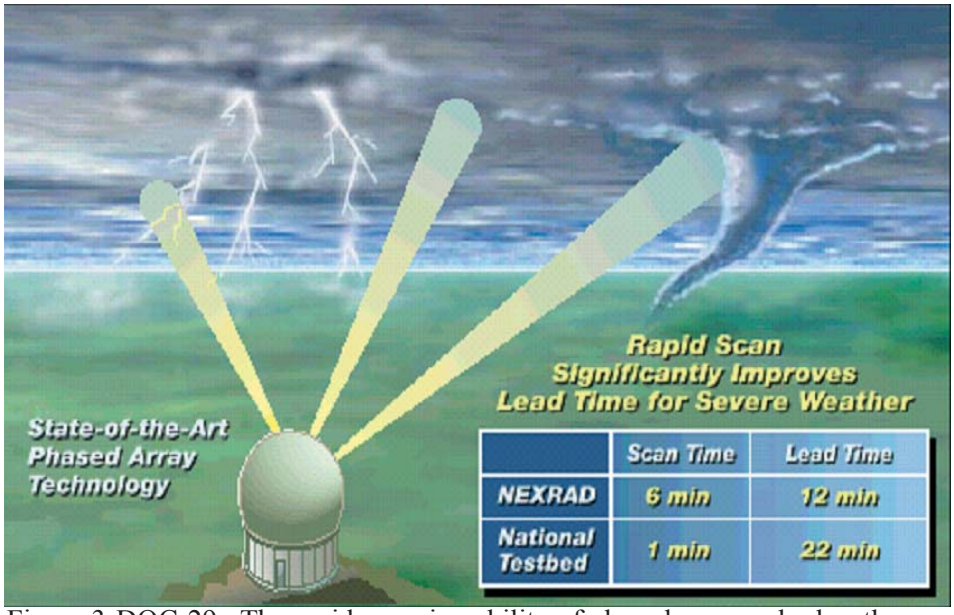


Figure 3-DOC-29. The rapid scanning ability of phased array radar has the potential to significantly increase the average lead times of tornado warnings.

Thus, a single network of multifunction phased array radar (MPAR) units could provide next-generation expansion of our current weather surveillance network, replace the Nation's aging air traffic surveillance radars, and meet homeland security and defense requirements for identifying and tracking non-cooperative craft operating over the U.S. homeland. MPAR will enable continued improvement of the Nation's severe weather warning system. It can provide adaptive sensing for warnings and nowcasts related to severe convective storms and the locally destructive effects of hurricanes (tropical cyclones) after they make landfall. Among the storm phenomena that could be tracked are tornadoes, strong wind gusts, hail, and locally heavy rains responsible for flash floods and mudslides. The enhanced weather surveillance provided by an MPAR network will provide economic benefits to domestic aviation and surface transportation systems. The agility and specificity of its multitasking beams will provide more detailed weather and atmospheric observations for urban meteorology, air quality nowcasts and forecasts, climate variability monitoring and forecasting, wildland fire monitoring and prediction, and atmospheric transport

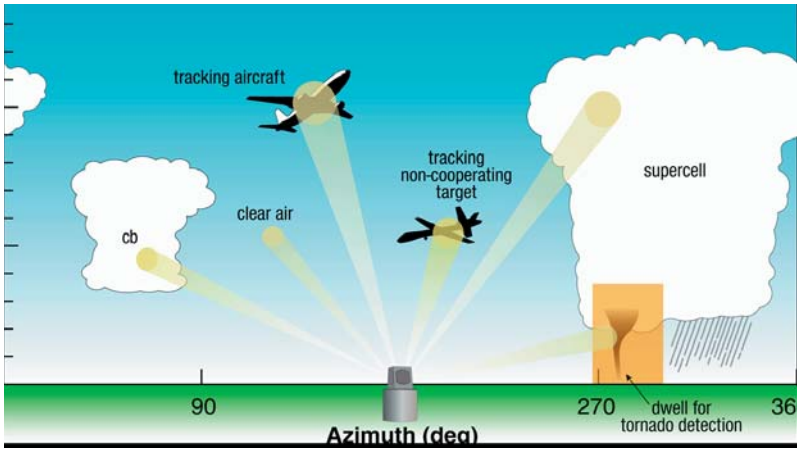


Figure 3-DOC-30. Electronically scanning phased array radars with no moving parts enable a single radar unit to perform multiple weather and atmospheric surveillance tasks and, at the same time, track multiple airborne craft.

and diffusion modeling. The non-cooperative aircraft surveillance capability of an MPAR network would complement the cooperative surveillance strategy planned for the Next Generation Air Traffic System (NGATS), while also addressing new craft tracking requirements of the Departments of Defense and Homeland Security. While research at NSSL is establishing the proof-of-principle for new applications of weather radar in these and other areas, the adaptive flexibility of MPAR will be essential in transferring these promising radar techniques to operations.

Because an MPAR network would replace multiple existing networks, it offers an affordable option to the alternative strategy of continuing with the existing civilian radar capability by repairing and eventually replacing aging units. Due to technology breakthroughs in radio frequency components, fueled by the wireless telephony and digital communications industries, the cost of a key MPAR component-the transmit-receive elements in an MPAR antenna-has dropped by orders of magnitude over the past 5 years, and this trend should continue. For a number of reasons, the operations and maintenance costs for MPAR units appear to be a third area of substantial savings relative to continuing to repair and replace current radar units as they age.

Thus, with respect to both capabilities and cost, MPAR is a promising option for meeting the Nation's future domestic radar surveillance needs. Using multiple beams and frequencies that are controlled electronically, NSSL has demonstrated phased array radar reduces the scan time of severe weather from six minutes for the NEXRAD radar to less than one minute, producing quicker updates of data and thereby potentially increasing the lead time for tornado warnings well beyond the current average of 13 minutes.

In support of improved understanding of the changing chemical composition of the atmosphere, the Field Research Division of the Air Resources Laboratory (ARL) has continued to refine its constant-level "smart" balloon. The smart balloon is intended to serve as a marker of parcels of air moving across the countryside and permitting samples to be made of the changes occurring in its composition. These balloons are being used both for air quality studies, such as the 2006 Texas study, and for hurricane research. The Field Research Division has also developed an Extreme Turbulence (ET) probe for measuring turbulence and surface fluxes in hurricanes. ET probes were successfully deployed into landfalling hurricanes in 2004, and plans are in place to eventually deploy them on moored NOAA buoys. The Oak Ridge Division of ARL continues to lead in the development of specialized sensors for measuring atmospheric turbulence. Their systems are now widely used for measuring the efficiency of coupling between the air and the surface, and have recently been selected for instrumenting the latest generation of research aircraft, manufactured in Italy.

In addition to the many weather related observing systems, OAR also dedicates significant time to improving the development, deployment, and monitoring of oceanographic related observing technologies and related data. As part of this effort, AOML manages the deployment of drifting buoys around the world, deploying some 300 new drifters annually and tracking nearly 700 as part of the Global Drifter Program. Using research ships, VOS, and U.S. Navy aircraft, Global Lagrangian Drifters (GLD) are placed in areas of interest. Once verified as operational, they are reported to AOML's Data Assembly Center (DAC). Incoming data from the drifter are then placed on the Global Telecommunications System (GTS) for distribution to meteorological services everywhere. The primary goal of this project is to assemble and provide uniform quality control of SST and surface velocity measurements. These measurements are obtained as part of an international program designed to make this data available in an effort to improve climate prediction. Climate prediction models require accurate estimates of SST to initialize their ocean component. Drifting buoys provide essential ground truth SST data for this purpose. The models also require validation by comparison with independent data sets. Surface velocity measurements are used for this validation.

In support of Global Climate Observing System (GCOS) requirements, OAR, in cooperation with NWS, the Office of Global Programs (OGP; housed within OAR), AOML,

and the Scripps Institution of Oceanography, maintains a network of approximately 100 meteorological drifting buoys in the Southern Hemisphere as part of the Southern Hemisphere Drifting Buoy Program. The buoys measure atmospheric pressure at sea-level, air temperature, surface sea water temperature, and surface currents. Observations are obtained through the ARGOS data collection and platform location system on-board the NOAA polar-orbiting satellites. The buoys are a subset of the Global Drifter Program.

The Tropical Atmosphere Ocean/TRIangle Trans-Ocean buoy Network (TAO/TRITON) array consists of approximately 70 Autonomous Temperature Line Acquisition System (ATLAS) and TRITON moorings in the tropical Pacific Ocean, telemetering oceanographic and meteorological data to shore in real-time via the ARGOS satellite system. Designed to improve detection, understanding, and prediction of El Niño, TAO/TRITON is a major component of the El Niño/Southern Oscillation (ENSO) Observing System, the Global Climate Observing System (GCOS), and the Global Ocean Observing System (GOOS). The array is supported primarily by the U.S. (NOAA) and Japan (JAMSTEC) with contributions from France (IRD) and Taiwan (NTU). The mooring array is maintained by the TAO Project Office located at the Pacific Marine Environmental Laboratory (PMEL) in Seattle, Washington. PMEL has responsibility for project management and logistics. The mooring array operations have recently been transferred to NWS. These buoys provide climate researchers, weather prediction centers, and scientists around the world with real-time data from the tropical Pacific. El Niño (the warm phase of the ENSO cycle) is associated with a disruption of the ocean-atmosphere system in the tropical Pacific and has important consequences for weather around the globe.

The Pilot Research Moored Array in the Tropical Atlantic (PIRATA) is a project designed as an extension of the TAO array into the Atlantic. The purpose of PIRATA is to study ocean-atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on seasonal, interannual and longer time scales. It consists of an array of 12 ATLAS moorings similar to those deployed in the Pacific. Planned expansion of the PIRATA array into the hurricane genesis region of the Atlantic will allow for a better understanding of ocean-atmosphere interactions on hurricane development and enhanced predictions of hurricane formation.

Figure 3-DOC-31. One of approximately 70 Autonomous Temperature Line Acquisition System (ATLAS) and TRITON moorings in the tropical Pacific Ocean.

In an effort to better understand and forecast climate, OAR has been deploying a global array of profiling floats since 2000. The broad-scale global array of temperature/salinity profiling floats, known as Argo, has already grown to be a major component of the ocean observing system with an intended deployment of 3000 floats. Argo floats are free-drifting profiling floats that spend most of their life "parked" at 1,000 or 2,000 meters depth in the ocean, regularly surfacing to make temperature and salinity profile measurements and providing those observations in real-time. As of August 2006, 2485 Argo floats have been deployed. The Argo array is part of the Global Climate Observing System/Global Ocean Observing System GCOS/ GOOS) and is a major contributor to the WCRP's Climate Variability and Predictability Experiment (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE). Along with satellites, Argo provides a quantitative description of the changing state of the upper ocean and the patterns of ocean climate variability from months to decades, including heat and freshwater storage and transport.

As part of the backbone for the Integrated Ocean Observing System (IOOS), OAR supports the national ocean observation backbone through 29 deployed or planned operational ocean moorings as part of the Ocean Reference Station network. The operational ocean moorings provide measurements of high quality air-sea fluxes of heat, moisture, and momentum that will be used to make regional assessments of flux components from numerical weather prediction models and satellites. A partnership with the National Science Foundation's ORION program will greatly enhance the capacity of the network.

HIGH IMPACT WEATHER RESEARCH

In addition to research and development of observing systems and related technology, OAR also focuses on ways to improve our understanding and the predictability of severe weather systems and their associated hazards. Providing significant national leadership in this area, the National Severe Storms Laboratory (NSSL) focuses on research to better understand such hazards as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms with the goal of helping the National Weather Service (NWS) improve forecasts and warnings. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instru-

mented aircraft, and lightning-location networks. NSSL's research includes assessment and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, with a focus on research and development, for the NWS WSR-88D radar program. In 2006, NSSL continued to develop techniques, in cooperation with the NWS, to forecast and warn of weather hazards to aviation and the general public.

NSSL's vision for the warning decision process continues to evolve as our scientists and engineers work toward integrating the next generation radar (MPAR) and storm-scale numerical models to create a storm-scale prediction capability for our National Weather Service partners. While it is not possible today, within the next decade we envision operational units using a "Warn on Forecast" methodology, e.g., a forecaster will use thunderstorm-resolving computer models for severe weather warnings in the same way as he/she does today with our current Doppler radar systems. It is believed that these enhancements to our operational weather capability will lead to a more accurate warning system which increases lead time and provides probabilistic information that enables the public to take the best reasonable action during a severe weather event.

During the spring and summer of 2006, NSSL conducted the Severe Hail Verification Experiment (SHAVE) with the goal of testing new technologies that will vastly improve the verification of severe weather events as well as the climate record of those events. SHAVE researchers documented hail swaths from severe thunderstorms at a high spatial and temporal resolution by integrating real-time meteorological data into Geographic Information Systems (GIS). This integration permitted the SHAVE team (NSSL/CIMMS scientists and University of Oklahoma students) to make verification phone calls to very specific locations. Rather than an average of 1-2 hail reports collected from each storm, SHAVE collected anywhere from 10-100 reports along the storm's paths at a much higher spatial resolution and with fewer time and space errors than in the official storm climate record (the Storm Data publication). Better verification data such as these are vital to future improvements to the warning process. These high-resolution data sets enable: (1) validation of new probabilistic warning techniques that would not otherwise be possible given the typically coarse spatial resolution of the severe event reports in Storm Data, (2) enhanced, independent verification of warnings issued by the National Weather Service, and (3) validation of high-spatial and temporal resolution hail detection tools.

Figure 3-DOC-32. Photo taken May 11, 1982, by NSSL storm intercept team in the hail core of a supercell thunderstorm that later produced an F2 tornado.

NSSL works with the Federal Aviation Administration's (FAA) Aviation Weather Research Program (AWRP) to develop weather radar applications that enhance the safety and efficiency of the aviation community and the National Airspace System. Work is focused on both convective weather and winter weather, with special attention to treating all WSR-88D radars within the continental U.S. as a single network. Such treatment allows NSSL to produce a single, authoritative 3-dimensional grid of radar data. Intensive research is also directed to polarimetric radar applications unique to aviation needs. Examples include winter time quantitative precipitation estimation, detection of icing conditions, and data quality issues unique to FAA users.

The NSSL is collaborating with the NWS Office of Hydrologic Development (OHD) and the Office of Climate Weather and Water Services in the development, testing, and research-to-operations of a 'state of the science' approach to quantitative precipitation estimation (QPE) and short-term precipitation forecasts (QPF). The goal of this cross agency collaboration is to increase warning lead times for the detection and prediction of flash floods and river flooding. This effort is part of the Advanced Hydrologic Prediction Services (AHPS), which is an essential component of the NWS Climate, Water, and Weather Services. The

research and development into QPE and QPF is being afforded by a Federal Aviation Administration and National Centers for Environmental Prediction collaboration towards the integration of radar networks into seamless high-resolution three-dimensional mosaics for use in aviation safety and atmospheric model data assimilation. NSSL has established the infrastructure and techniques for ingesting domestic and international weather surveillance radars, along with integrating satellite and surface observations, to facilitate research and development toward advance monitoring of the Nation's fresh water resources. The vision and objectives of the research is to improve the capability to effectively manage the Nation's fresh water resources and to mitigate the social and economic impacts of flooding through timely and accurate detection and prediction of precipitation.

NSSL continues to lead a project called CI-FLOW (Coastal-Inland Flood Observation and Warning) that uses NSSL's multi-sensor rainfall estimates to drive an NWS distributed hydrologic model that predicts streamflow to help NWS improve flash flood warnings. In addition, the streamflow information is used to drive three models run by our partners at N.C. State University, a water quality model, estuary model, and storm surge model. This system of coupled models, when fully integrated, can be used for land-use studies, algal bloom studies, pollution studies, inundation studies of landfalling tropical systems, for example.

NSSL is participating in NOAA's Hydrometeorological Testbed or HMT. The HMT is a NOAA-led research activity with several external partners (e.g., universities, water management groups, etc.). The objective of the overall HMT program, of which HMT-West is the first full-scale deployment, is to accelerate the infusion of new technologies, models, and scientific results from the research community into daily forecasting operations of the National Weather Service and its River Forecast Centers. The research activities in HMT-West this year focused on deployment of NSSL's SMART-R radar system to observe heavy rainfall events over the American River Basin near Sacramento, California. Twelve storm systems were observed and unprecedented data sets were collected in FY 2006.

NSSL has been working with U.S. Geological Survey (USGS) and NWS scientists to improve the debris flow warnings for Southern California. Recent fires in the foothills can lead to devastating debris flows (mudslides) when subsequent storms deposit relatively modest rains on those foothills. The USGS instrumented a recent burn area (the Harvard fire region near Burbank California) for high resolution studies in order to refine the warnings thresholds. NSSL contributed a mobile radar to make high-resolution radar estimates of precipitation over the Harvard burn area this last winter. Five rainstorms were observed, of which 2 produced moderate debris flows.

Improvement of short-range (1-12 hour) forecasting will be accomplished by the development and evaluation of new local data system technologies and techniques, many of which can be incorporated into operational weather forecasting in the near term. GSD develops and evaluates state-of-the-art workstations for forecast office environments. Specifically, GSD has and will continue to develop capabilities to allow the forecaster to integrate, view, and manipulate observations from current and planned meteorological sensing systems using computer-assisted data display and synthesis techniques. NSSL is collaborating with NWS and GSD to integrate some of NSSL's advanced single and multi-radar display capabilities into AWIPS.

GSD will continue efforts toward effective assimilation of diverse observational data into numerical prediction models. Data from the Aeronautical Radio Incorporated (ARINC) Aircraft Communications, Addressing, and Reporting System (ACARS); WSR-88D Doppler radars; and weather satellites, especially Geostationary Operational Environ-mental Satellite (GOES), are frequent and provide unprecedented resolution, either in the vertical or the horizontal, or both. These data are being more fully exploited in the Local Analysis and Prediction System which provides highly detailed analyses and forecasts over areas hundreds of kilometers on a side, and the Mesoscale Analysis and Prediction System, the basis for operational and frequent short-term forecasts for the lower 48 states. The system has been incorporated into the AWIPS system and is being used by a number of other agencies, not only for various regions of the U.S., but for a number of regions throughout the world.

OAR will continue to transfer knowledge of Doppler radar applications, severe weather systems, and heavy rainfall events; much of the transfer is through courses at the NWS training center. Visits and interactions with NWS centers, regional headquarters, and forecast offices continue and NSSL is participating directly in training programs, such as COMET in Boulder, Colorado, and the WSR-88D Operational Support Facility in Norman, Oklahoma.

A multi-year program of coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). This program also involves ESRL and NSSL, the Seattle NWS Forecast Office, the National Center for Atmospheric Research (NCAR), and the University of Washington. Support for the program is also being provided by the Office of Naval Research. This research improves understanding of the effects of promi-

nent terrain on West Coast weather, with the ultimate goal of providing improved forecasts of coastal winds, precipitation, sea state, and storm surges. The emphasis is on the upstream effects of the coastal terrain in the storm environment when the background forcing is strong and the coastal forecasts are most critical. The approach involves special field observations and diagnostic studies using experimental numerical simulations. Field work featuring a NOAA WP-3 research aircraft in the 1990s, for example, has yielded meteorological data for the Pacific Northwest coast with low-level winds of up to 85 knots, in the vicinity of strong fronts and, in one case, an intense, landfalling low pressure system. The case studies from this work provide immediate insights on the influences of the coastal terrain on landfalling storms, and high quality data sets for numerical model initialization and validation. Follow-up field programs in FY 2004 and FY 2005 focused on cloud and precipitation processes using special observations from research aircraft and land-based radars. The results are providing information on how to improve forecasts of storms in the Western U.S.. This activity is also coordinated with the NWS Office of Hydrologic Development and NCEP's Climate Prediction Center for support to hydrologic resource forecasting to help better forecast floods and droughts.

MESOMETEOROLOGY AND PRECIPITATION FORECASTING AND WARNING RESEARCH

In support of NOAA's goal of protecting lives and property, OAR contributes to the development of techniques to improve short term forecasters of significant weather events. Through detailed case studies and regional climatologies, National Severe Storms Laboratory (NSSL) scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storm complexes. Field programs were carried out and followed by extensive analyses were conducted to improve the science behind technology advances. Example programs whose data have been and continue to be analyzed include (1) the Severe Thunderstorm Electrification and Precipitation Study (STEPS) in 2000, (2) the International H2O Project (IHOP), (3) the Thunderstorm Electrification and Lightning Experiment (TELEX) 2003 and 2004, and (4) the annual collaborative severe storm research by NSSL, the NWS/SPC, and collaborators.

Other NSSL studies underway are focused on the precipitation structure of large storm systems (mesoscale convective systems), the interactions between meso-convective systems and the larger environment, the use of satellites to infer storm development and rainfall, short-range ensemble forecasting techniques, and winter storm forecasting procedures. Findings from these research activities lead to supporting the forecasting of a variety of high impact weather events.

NSSL will continue to investigate various model convective parameterization schemes, along with techniques to improve model initialization through four-dimensional data assimilation. Advances continue in numerical simulation and forecasting at mesoscale and stormscale resolutions. Current research is using data assimilation by ensemble Kalman Filter method, as well as lightning data assimilation, to improve forecasting of convection. At stormscale, pure simulation is also employed for improving understanding of dynamics, microphysics, and lightning. Toward the goal of improving operational mesoscale model and human forecasts of storms and their environments, NSSL researchers investigate the convection initiation (CI) process and the types of observations required to represent CI and storms in both research and operational mesoscale analysis and forecast model systems.

In 2002, NSSL contributed expertise and ground-based mobile radar, mobile mesonets, and mobile sounding observations during the International H2O Project (IHOP) conducted on the U.S. Southern Great Plains (SGP). The chief aim of the 2002 IHOP campaign is improved characterization of the four-dimensional (4-D) evolution of water vapor and boundary layer (BL) structure with application toward improving the prediction of convective storms. The SGP region is an optimal location due to existing experimental and operational facilities, strong variability in moisture, and active storms and convective systems providing most of the warm season precipitation east of the Rocky Mountains. Recent studies report a new method for objectively combining diverse radar and in-situ measurements to obtain internally consistent analyses of BL evolution and cloud formation with application to cases that illustrate the impact of drylines and cold fronts on the CI process. Given sound conceptual models of the CI process, forecasters in turn can interpret available observations more precisely to improve specificity and accuracy of storm forecasts. Another recent study reports the potential improvement of mesoscale model initialization via the assimilation of all types of real-time total and cloud-to-ground lightning observations to improve representation of ongoing convection and its integrated effects on model initial conditions.

NSSL has also made advances in interpreting lightning data in forecasting. This information will point to new ways for the National Weather Service to use lightning observations to improve forecasts and warnings of hazardous weather. NSSL operates state-of-the-science facilities that include the KOUN radar in Norman, which is a WSR-88D radar modified

with polarimetric parameters to provide information about the particle size and water phase of precipitation and the Oklahoma Lightning Mapping Array (LMA). The OK-LMA is a network of 11 stations in central Oklahoma that continuously maps in high space and time resolution the structure of all types of lightning in three-dimensions out to a range of 75 km and in two-dimensions out to a range of 200 km. All the technology advances and research findings are aimed at NSSL's contribution to advances in forecasting high-impact weather events.

NSSL is working with the NWS Storm Prediction Center (SPC) to improve the nation's ability to forecast severe weather and to enhance severe winter weather guidance products. Data collected during the IPEX campaign held in 2001 should help. The data are being analyzed by NSSL, SPC and University of Utah scientists. The IPEX field and research program was designed to improve the understanding, analysis, and prediction of precipitation and precipitation processes in complex terrain. Data analysis of IPEX continue in 2005. In addition, the SPC/NSSL collaboration has led to improvements in the way we understand convection initiated near the dryline and tornadoes spawned by hurricanes. A major forecast challenge for SPC forecasters is severe weather from elevated convection. Recent collaborative research shows the spatial and temporal distribution of such severe weather reports and begins to provide insight into processes that would improve our ability to forecast these events.

Figure 3-DOC-33. The OU Doppler-on-Wheels and the NSSL mobile laboratory take measurements of a snowstorm in Idaho during IPEX.

NSSL has developed a unique and vibrant collaboration with the operational forecasting community, which has recently been formalized with the establishment of the NOAA Hazardous Weather Testbed (HWT). The mutual interests of forecasters from the NOAA Storm Prediction Center, researchers from NSSL, and collocated joint research partners from the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) inspired the formation of the HWT. The testbed's activities have been varied, including activities such as daily map discussions involving imminent severe weather, loosely-related research projects involving 2-3 collaborators, and periodic intensive collaboration periods with larger groups. But the cornerstone of the testbed has been the SPC/NSSL Spring Program, a series of annual experiments that attracts 50-60 researchers and forecasters to Norman each year.

The premise of each Spring Experiment is to provide forecasters with a first-hand look at the latest research concepts and products, while immersing research scientists in the challenges, needs, and constraints of front-line forecasters. In practice, this program gives forecasters direct access to the latest research developments while imparting scientists with the knowledge to formulate research strategies that will have practical benefits. The end result is not only better severe-weather forecasts, but important contributions to the scientific literature as well. Science partners in recent Spring Experiments have included NCAR, NCEP/EMC, OU/CAPS, and numerous academic centers.

As the Norman meteorological community consolidates its diverse workforce in a common building, numerous groups are adopting the collaborative spirit and innovative approach of the HWT. At the same time, the HWT is expanding to embrace these groups and provide the framework for development and implementation of new technologies in different areas, particularly those focusing on shorter-timescale forecasting challenges. For example, NSSL's Severe Weather Warning Applications and Technology Transfer (SWAT) team and the NWS Norman WFO are stepping into important leadership roles within the HWT.

NSSL anticipates that the proof of concept established through the annual NSSL/SPC Spring Experiment and the early years of the HWT will play an important role in bringing together the diverse elements of the Norman meteorological community and like-minded meteorologists from across the country. In fact, Congress recently provided seed funding to help foster a collaboration between the HWT, the University of Alabama at Huntsville, and NASA's Short-term Prediction Research and Transition Center (SPoRT), a joint center staffed by NASA research meteorologists also located in Huntsville, and the Huntsville WFO. The group in Oklahoma is being referred to as HWT/Norman and the groups in Alabama are being referred to as HWT/Huntsville. The HWT/Norman has decades of experience on severe weather and tornadoes characteristic of the central plains (long-lived supercell thunderstorms, for example), while the HWT/Huntsville has experience with the severe weather and tornadoes that are characteristic of the southeast U.S. (especially those spawned by land-falling tropical systems). Working together, we believe these groups will strengthen the nation's collective knowledge and understanding of these hazardous convective events, leading to significant contributions to the science and improved severe-thunderstorm and tornado watches and warnings for the public.

NSSL has been on the forefront of short-range ensemble forecasting and exploring the use of ensembles for forecasts of severe weather. During the summers of 2002 through 2004, NSSL was a partner in the New England High-Resolution Temperature Program. The role of NSSL was to provide several model forecasts and collect forecast data from NCEP and FSL and develop post-processing techniques to improve upon Model Output Statistics. A simple yet powerful bias correction approach was developed in which the past 12 days of model data and observations are used to bias correct today's forecasts. Results indicate that the bias-corrected ensemble forecasts improve upon MOS and also provide reliable probabilistic forecast information. In addition, a novel approach to providing reliable probabilistic quantitative precipitation forecasts was developed and tested. In 2003, NSSL in partnership with the SPC embarked on an experiment to test the value of human forecasters in creating ensemble initial condition perturbations. Results indicate that human-generated ensemble perturbations can contribute positively to ensemble skill for severe weather events, indicating that the knowledge and experience of forecasters needs to be put to better use as we learn how to design ensembles for a variety of end users. With ensembles a regular part of the NCEP operational suite, approaches such as bias correction and human-generated ensemble perturbations as crucial to making best use of the model forecast data for both routine and severe weather forecasts.

Mesoscale dynamics research at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey, develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies. (Figure 3-DOC-20). Current research focuses on extending these activities to the global domain through state-of-the-art global atmospheric models.

In 1994, the Global Systems Division (GSD) of ESRL implemented a Rapid Update Cycle (RUC) model at the NWS National Centers for Environmental Prediction (NCEP) and continues to provide periodic follow up upgrades. The RUC provides a new analysis of surface and atmospheric conditions every three hours as well as short-range predictions for the next 12 hours. This information is useful to forecasters at local NWS offices around the country and also supports commercial and general aviation.

A higher-resolution, higher-frequency version of the RUC was implemented at NCEP in 2005. The 13-km version of NOAA's Rapid Update Cycle (RUC13) model became operational at 1200 UTC Tuesday 28 June 2005, at the National Centers for Environmental Prediction (NCEP). This is a major milestone for improving the RUC high-frequency short-range forecasts for NOAA and external users, especially for aviation and severe weather forecasting. The main changes include higher horizontal resolution (from 20 km to 13 km), improved data assimilation especially for moisture/cloud fields, and improved cloud/precipitation physics. Most notable improvements are in surface and cloud/precipitation forecasts, resulting in part from assimilation of new observation types in the RUC13. The model updates every hour, incorporating information from virtually all high frequency data sources: hourly wind profiles; WSR-88D (Doppler radar) velocity azimuth displays; ACARS reports (up to 65,000 per day); cloud-drift winds and estimates of total precipitable water vapor from the GOES satellites; and surface obser-

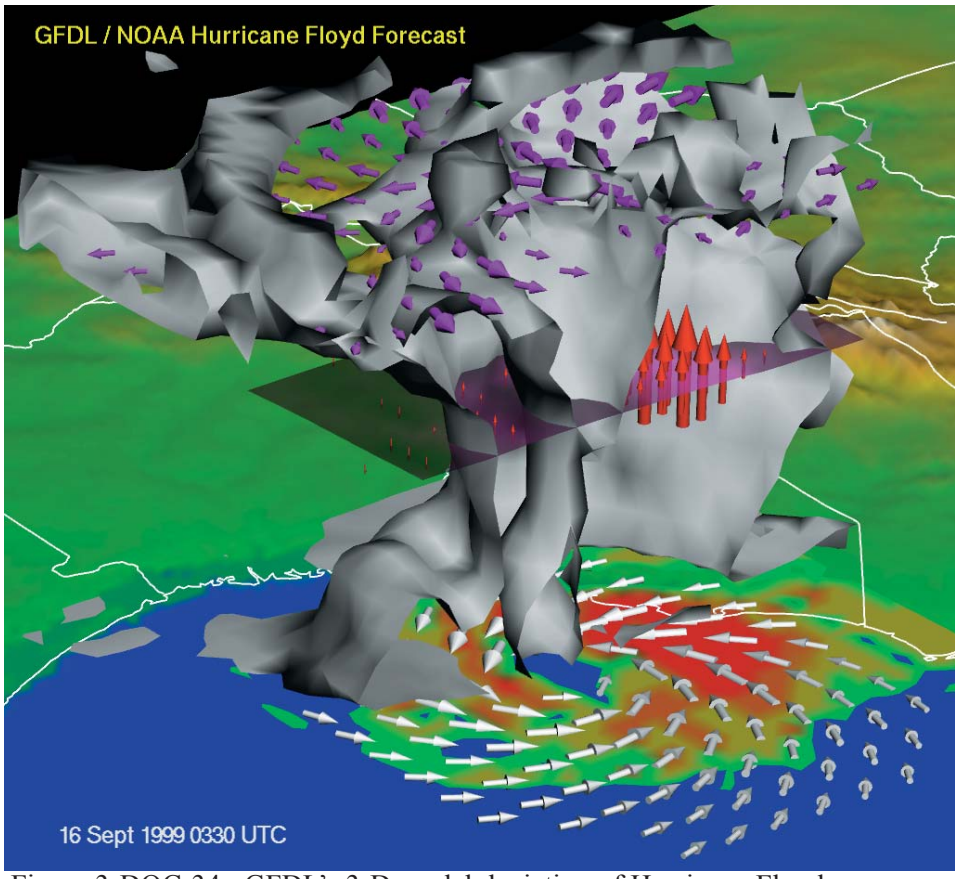


Figure 3-DOC-34. GFDL's 3-D model depiction of Hurricane Floyd.

vations. The new RUC also includes explicit forecasts of cloud droplets, ice crystals, raindrops, snowflakes, and graupel (snow pellets). This improves forecasts of precipitation type. The RUC exploits a new, multi-level soil and vegetation model to improve forecasts at and near the earth's surface.

Along with NCAR, NCEP, and the university community, GSD is collaborating on the development of a new mesoscale model, the Weather Research and Forecast (WRF) model. The goal is to have the WRF model become a community model and a tool both for experimental and operational prediction, thus paving the way for quick realization of research advances in forecast dissemination to the public and industry.

The Air Resources Laboratory (ARL) is also involved in the development of new models for operational use by NCEP. The main focus is on mesoscale models and in the development of new capabilities for data assimilation. In particular, the new generation of mesoscale models (such as the WRF model referred to above) will require advanced descriptions of the coupling between the air and the surface, a matter that is being studied intensively in ARL programs involving closely interacting measurement and modeling activities. To this end, ARL continues to work closely with the Chemical Sciences Division (CSD) of ESRL to maintain the nation's surface radiation network (SURFRAD), data from which are now routinely employed to test both forecast mesoscale models (such as the Eta model) and satellite outputs. ARL conducts research on the surface energy balance and on the spatial variability of surface fluxes using aircraft. In addition, ARL serves as the provider of the NCEP modeling capability to address situations of atmospheric dispersion, such as of emissions from sources like volcanos, industrial enterprises, and nuclear accidents. In recent work, ARL is adapting a new system developed to forecast dispersion of smoke from forest fires, in a study performed in collaboration with the Association of South East Asian Nations, the U.S. Forest Service, and The Mediterranean Centre for Environmental Studies Foundation. The present program will provide interim products to the joint NOAA-EPA Air Quality Forecasting Program to improve smoke dispersion estimates in the particulate forecast model.

TROPICAL ATMOSPHERIC RESEARCH

The Tropical Dynamics and Climate Program of the ESRL Physical Sciences Division (PSD) is using precipitation profilers to study the structure, evolution and variability of precipitating cloud systems in the tropics and elsewhere. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. A recent focus of research with profilers has been to provide ground validation research in support of satellite precipitation measurement missions such as the NASA Tropical Rainfall Measuring Mission (TRMM). These observations have provided important information on the vertical structure and temporal evolution of precipitating cloud systems during TRMM Ground Validation field campaigns. The observations made during the field campaigns are the subject of collaborative research with other TRMM researchers with an emphasis on the use of profilers to calibrate scanning radars used for TRMM ground validation research and the use of profilers to retrieve drop-size distributions and related precipitation parameters of interest to the TRMM Science Team. Validation of drop-size distributions used in algorithms is key to improving the retrieval of rainfall estimates from the TRMM satellite data. The profiler-based precipitation research described above also can be used to provide calibration of NEXRAD scanning radars as has recently been demonstrated for Melbourne, Florida. In related activities PSD is carrying out hydrometeorological studies in collaboration with the NWS in demonstrating the value of hydrometeorological testbeds as a means of improving the transition of scientific advances to operations.

HURRICANE ANALYSIS AND PREDICTION RESEARCH

The Atlantic Oceanographic and Meteorological Laboratory's Hurricane Research Division (HRD) mission is to advance the understanding and prediction of hurricanes and other tropical weather. HRD's research is based on a combination of models, theories, and observations, with particular emphasis on data obtained with research aircraft. The goals of this research are to:

- Advance the prediction of tropical cyclone intensity change by improving understanding of the processes that modulate internal storm dynamics and storm interactions with the atmosphere and ocean;
- Improve the prediction of tropical cyclone tracks by enhancing understanding of the interactions between a tropical cyclone and its environment through an optimal analysis of field observations;
- Improve the understanding of and ability to predict tropical cyclone frequency and intensity on intraseasonal, interannual, decadal and longer time scales; and
- Enhance the ability to diagnose and predict the impact of tropical cyclones on life and property through wind, rain, waves, and storm surge.

These goals are accomplished by:

- Designing and conducting research experiments in the hurricane to collect and provide data for research and applications;
- Analyzing these data sets and publishing the research in the refereed lit-

erature;

• Developing new technology and applications based on this research to improve NOAA's products; and

• Providing outreach to the public through the WWW, conferences, presentations, and other means.

Much of HRD's research is based on the in-situ and remotely-sensed observations in the inner core of tropical cyclones and their surrounding environment. These observations are primarily collected in our annual field program using the two NOAA turboprop aircraft and jet operated by the NOAA Aircraft Operations Center (AOC). The field program is used to carry out scientific experiments designed to address the goals stated above. Data sets gathered by these experiments, combined with dynamical and statistical models and theoretical development, range from global to microscale, forming the cornerstone of research in HRD. Because of this extensive field experience, HRD scientists are recognized internationally for their knowledge of tropical cyclones as well as their expertise in technological areas such as airborne Doppler radar, dropsondes, cloud microphysics, and air-sea interaction, to name a few. These assets make HRD unique worldwide, and provide NOAA a unique capability.

In 2005, NOAA's HRD began a multi-year experiment called the Intensity Forecasting Experiment (IFEX). Developed in partnership with NOAA's Environmental Modeling Center (EMC), National Hurricane Center (NHC), Aircraft Operations Center (AOC), and National Environmental Satellite Data Information Service (NESDIS), IFEX is intended to improve the prediction of hurricane intensity change by:

1. collecting observations that span the tropical cyclone lifecycle in a variety of environments;
2. developing and refining measurement technologies that provide improved real-time monitoring of tropical cyclone intensity, structure, and environment; and
3. improving our understanding and prediction of the physical processes important in intensity change for a tropical cyclone at all stages of its lifecycle.

Observations are collected in a variety of tropical cyclones at different stages in their lifecycle, from formation and early organization to peak intensity and subsequent landfall, decay over open water, or extratropical transition. These observations also aid in the improvement of operational models and the development of the next-generation operational hurricane model, the Hurricane Weather Research and Forecasting (HWRF) model system. There are several unique aspects of IFEX in 2006, that will help improve our understanding and prediction of hurricane intensity change. Some examples are provided below:

• Hurricane genesis experiment - Take data to improve our knowledge of the evolution of tropical waves to tropical storms.

• Impact of Saharan air on intensity forecast models - Recent research has shown that very dry air originating from the African continent, called the Saharan Air Layer (SAL), may be an important factor in hurricane intensity change.

• Doppler Radar - Mapping of the center wind field from airborne tail Doppler radar and its transmission to EMC and NHC in real-time.

• The 2006 international African Monsoon Multidisciplinary Analysis (AMMA) and NASA AMMA (NAMMA) field campaigns are concurrent research efforts that will compliment NOAA's IFEX research goal to observe and describe intensity change in storms developing off the African coast. Much of NOAA's tropical cyclone research will be coordinated with AMMA and NAMMA in 2006 with a focus on investigating the SAL, and how it interacts with developing hurricanes.

HRD coordinates its programs with other NOAA organizations, e.g., AOC, NESDIS, and NCEP, in particular with EMC and NHC. HRD maintains active research programs with, and receives funding from other governmental agencies, in particular, the Department of the Navy's Office of Naval Research (ONR) and the National Aeronautics and Space Agency (NASA).

In program areas where it is beneficial to NOAA, HRD arranges cooperative programs with scientists at the National Center for Atmospheric Research, and at a number of universities. For example in 2004, HRD part-

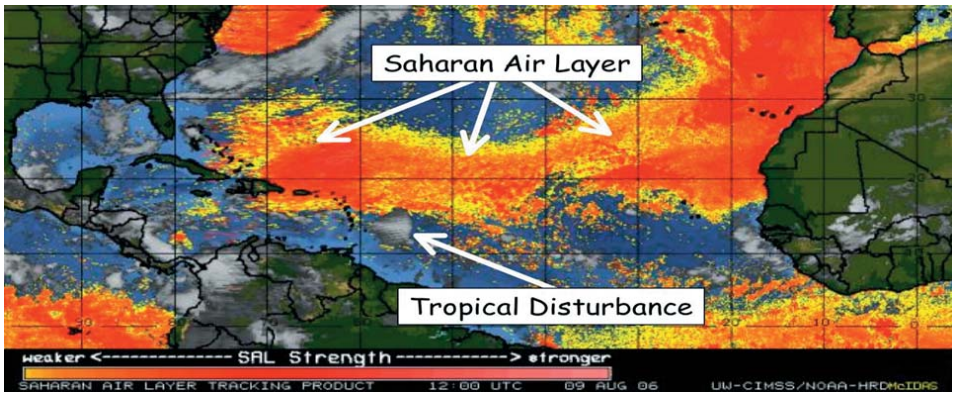


Figure 3-DOC-35. This August 9, 2006 infrared satellite image from NOAA's GOES satellite shows a Saharan Air Layer (SAL) outbreak (yellow to red shading) spanning nearly 4,000 miles across the North Atlantic. A tropical disturbance is indicated along the southern periphery of the SAL and was likely being suppressed by the SAL's dry dusty air and strong mid-level winds.

nered with ONR-sponsored university and Federal scientists on the Coordinated Boundary Layer Air-Sea Transfer (CBLAST) experiment focused on improving numerical model parameterization of the air-sea transfer of energy that fuels the storms. HRD also integrated two recent NASA Convective and Moisture Experiments (CAMEX-3, 4) in 1998, 2001. Finally, in 2005, HRD partnered with the NASA-sponsored Tropical Cloud Systems and Processes (TCSP) experiment and the NSF-sponsored Hurricane Rainband and Intensity Change Experiment (RAINEX) to compliment NOAA's IFEX research goals.

Under the USWRP and its participating agencies, OAR, NWS, and the National Environmental Satellite Data Information Service (NESDIS) established a Joint Hurricane Testbed (JHT) at the Tropical Prediction Center in Miami, Florida, in 1999 (http://www.nhc.noaa.gov/jht/index.shtml). This testbed is where the hurricane research is evaluated for operational use and those research products passing the test will be handed off to operations.

NUMERICAL ANALYSIS AND PREDICTION MODELING

As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved numerical weather prediction models. Three groups at GFDL are engaged in weather research activities: Climate Dynamics and Prediction, Weather and Atmospheric Dynamics, and Atmospheric Physics and Chemistry.

The Goal of the Climate Dynamics and Prediction Group is to develop and use computer models of the atmosphere-ocean- ice-land system in order to:

• Identify and elucidate the physical and dynamical mechanisms which maintain climate and cause its variations on seasonal to centennial time scales;

• Assess and understand the predictability of the climate system on seasonal and longer time scales, including the El Niño phenomenon; and

• Evaluate the impact of human activity on the Earth's climate system

This group is charged with studying and modeling climate phenomena on seasonal to multi-century time scales. The group's work is highly relevant to key elements of the NOAA Strategic Vision, especially Mission Goal 2 to "Understand climate variability and change to enhance society's ability to respond". In addition to examining a wide range of climate time scales, various members of the group have expertise spanning the expansive set of complex and interconnected parts that together constitute the Earth's physical climate system (this includes the atmosphere, ocean, land surface and sea ice). Group members participate in the development, testing, application, and analysis of numerical models of the climate system. Running on supercomputers, these models are the research tools used by group members to both advance our understanding of the Earth's climate system and to generate products relevant to assessment and policy decision support.

The Weather and Atmospheric Dynamics Group at GFDL improves our understanding of atmospheric circulations ranging in scale from hurricanes to extratropical storms and the general circulation, with an emphasis on extreme weather events and the interplay between weather phenomena and climate variability and change, using high resolution atmospheric modeling as the central tool. This effort is augmented by the Atmospheric Physics and Chemistry group, which performs research to improve our understanding of the interactive three-dimensional radiative-dynamical-chemical-hydrological structure of the climate system from the surface and troposphere to the upper stratosphere and mesosphere on various time and space scales. This is achieved by employing meteorological observations in conjunction with models for diagnostic analyses of atmospheric processes, and evaluating and improving parameterizations employed in weather and climate models; modeling the interactions between clouds, convection, radiation and large-scale dynamics to understand their roles in climate and climate change; and modeling the physics, chemistry and transport of atmospheric trace gases and aerosols to investigate the impact of future emissions on regional and global air quality, and to investigate the regional and global climatic effects due to changes in natural and anthropogenic radiatively-active species.

AIR QUALITY RESEARCH

The principal mission of the Air Resources Laboratory (ARL) is to improve the capability to forecast changes in air quality and atmospheric deposition. Deposition is the factor that links the pollutant characteristics of the air with the terrestrial and aquatic environments. ARL's research focuses on the lower atmosphere, where the atmosphere is in direct contact with other media-- aquatic, terrestrial, and biospheric. The core of ARL research relates to studies of the atmosphere as a component of the total environment. Much of this work is in collaboration with other parts of NOAA (principally NCEP) and with other agencies, such as EPA, DOE, and the DoD.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs, and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Car-

olina, develops predictive models on local, regional, and global scales for assessing changes in air quality and air pollution exposure as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the EPA on air pollution control strategies for attainment and maintenance of ambient air quality standards, and for the provision of ozone and particulate matter forecasts in support of the joint NOAA-EPA Air Quality Forecasting program.

The ARL Atmospheric Turbulence and Diffusion Division, in Oak Ridge, Tennessee, conducts studies to improve understanding of atmospheric transport, diffusion, and air-surface exchange processes, and to develop new predictive models.

The ARL Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales. The ARL Special Operations and Research Division (SORD) in Las Vegas, Nevada conducts research on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness and emergency response activities. SORD also serves as the main NOAA facility working with the Cooperative Institute for Atmospheric Studies and Terrestrial Applications (CIASTA) of the University of Nevada system.

ARL participates in two national networks that direct research attention on the needs of the next generation of predictive models. The Atmospheric Integrated Research Monitoring Network (AIRMoN) is a nested-network with sites of varying complexity addressing evolving scientific issues of wet and dry deposition from the atmosphere. A major current item for scientific attention is the atmospheric deposition of nitrogen compounds and its role in promoting eutrophication of ecosystems, primarily coastal. The ARL-developed Integrated Surface Irradiance Study (ISIS) serves as the national array of monitoring stations for solar radiation (and ultraviolet-B) with a subset of more advanced stations (the SURFRAD array) where both incoming and outgoing radiation components are monitored. Many of the SURFRAD stations are augmented with instrumentation to measure fluxes of sensible heat, latent heat, momentum, and carbon dioxide. Thus, the SURFRAD program is evolving into one of complete energy balance with supporting data on carbon dioxide exchange. ISIS and SURFRAD are presently operated by Chemical Sciences Division (CSD) of ESRL. This work forms an intersection with the new flux measurement networks in the U.S. and overseas, referred to as "Ameriflux" and "Fluxnet." All of this work is coupled with ARL research on atmospheric aerosols and with the development of new automatic methods for measuring cloud cover.

Much of ARL's research focus is on expressing air surface exchange processes in numerical models. To this end, ARL scientists have been instrumental in developing methods for describing an air surface exchange appropriate for use with model grid cells of several tens of kilometers on a side. To test the aerial integration capabilities, ARL has instrumented an aircraft of the NOAA fleet (a DeHavilland Twin Otter) to measure all of the eddy fluxes as well as a number of trace gas exchange rates. This instrumented aircraft has been used in several field experiments and has already demonstrated that considerable error can result when local values are inappropriately taken to represent larger areas.

ARL also provides forecast support to NOAA's emergency response systems with emphasis on chemical, nuclear, and volcanic events. For this application, ARL develops and couples advanced dispersion models with the forecast products of the NWS to provide a basis for trajectory and dispersion calculations. The models in question are now widely accepted. The Hazardous Atmospheric Release Model (HARM) is operationally employed at a number of DOE locations. The ARL Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model is now operational in many countries, including China and Australia, as the national dispersion forecasting capability. It also serves the NWS in this role. Registered users can also access HYSPLIT products via the Internet. HYSPLIT is the major product employed in the operations of the Regional Specialized Meteorology Center (RSMC) set up as a joint undertaking of ARL and NCEP under the auspices of the World Meteorological Organization (WMO). The WMO/ RSMC is the source of dispersion products in the event that a pollution plume (in this case, radioactive) crosses international boundaries.

The provision of dispersion forecasts by ARL scientists extends to two specific areas of special relevance - the Nevada Test Site and the Idaho National Laboratory. ARL maintains staffs of dedicated dispersion meteorologists at each location, where site-specific models are developed and run using data generated by dedicated regional networks of meteorological sensors. These sites also serve as research testbeds for improving ARL's dispersion models, such as the HYSPLIT model.

Each of ARL's divisions also partici-

pates in a cooperative agreement designed to explore the synergy that can be accomplished by collaboration between the government and private industry. The focus is the use of private sector data to address homeland security threats and potential local accidental events, as well as protection of the general population through the provision of better data in response to weather and climate related events. The intent of the program is to address threats where most of the population lives - in cities - exploring the use of the large non-government database that is available to most cities for use in the next generation of computer models.

The Chemical Sciences Division (CSD) of ESRL coordinates the Health of the Atmosphere air quality research effort. NOAA's Health of the Atmosphere research is focused on the atmospheric science that underlies regional and continental air quality, with the goal of improving our ability to predict and monitor future changes, leading to improved scientific input to decision-making. CSD, ARL, GMD, GSD, PMEL, and PSD participate in the research. The Health of the Atmosphere research goals are:

• Characterize regional ozone episodes: Characterize the factors that cause poor air quality in regions of the U.S. where excessive levels of ground-level ozone and fine particle pollution are occurring. In the summers of 2002 and 2004, two major field investigations were carried out to characterize air quality in the New England region. Ground-based measurements, ship and aircraft measurements, forecasting, and modeling analyses were applied in the research. Among the processes investigated were the role of nighttime chemistry in the formation of ozone pollution, the role of the sea-breeze/land-breeze circuit in influencing New England's air quality, and the role of the marine boundary layer as a conduit for the movement of pollutants throughout the region.

• Document trends in air quality: Help evaluate predicted atmospheric responses to changes in emissions (i.e., the ongoing measurements provided by the Atmospheric Investigation, Regional Modeling, Analysis and Prediction (AIRMoN) and the ozone profiling networks).

• Develop a better understanding of the fundamental science underlying the processes responsible for the formation and distribution of fine particles in the atmosphere to improve the atmospheric predictive capability that links sources of fine particles and their precursors to human exposure and visibility impairment.

Under the future Health of the Atmosphere research umbrella, the OAR Laboratories integrate their meteorological, chemical, and forecasting expertise to support an assessment and prediction capability for regional air quality that incorporates the influence of multiple-timescale meteorology/climatology. While the ambient levels of pollutants like ozone and fine particles are clearly dependent on pollutant emissions, the variation in those levels is also driven by meteorology, both in the short term and longer term. Therefore, assessing both the intended long-term improvements in air quality and the more-episodic variations requires an understanding, not only the atmospheric linkages between emissions and concentrations, but also in understanding the coupled chemical and meteorological processes. Research efforts will also focus on an evaluation and improvement of the tools used to forecast future air quality and the observing systems needed to evaluate their skill.

This approach was used in the summer 2004 New England Air Quality Study (NEAQS), which built on the groundwork laid by the scoping study done as NEAQS 2002. In 2004, NEAQS was conducted in cooperation with other agencies' complementary field studies as the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT). Observations were made from an array of platforms that includes a dozen aircraft, the NOAA research vessel Ronald H. Brown, and several ground sites in New England, Canada and Europe. NEAQS will help provide the scientific understanding required to underpin the region's future efforts to improve air quality for its citizens and required to develop advanced air quality forecast capabilities.

NOAA is leading a similar effort in East Texas during the Summer/Fall of 2006. Two NOAA aircraft and the research vessel Ronald H. Brown are being deployed to East Texas and the

Figure 3-DOC-36. The research vessel, Ronald H. Brown.

Gulf of Mexico in a joint air quality-climate study. NOAA is working with the local air-regulatory agency, the Texas Commission on Environmental Quality (TCEQ), university researchers, and scientists from sister Federal agencies (NASA, EPA and DOE) to better understand the causes of, and potential solutions for, poor air quality in the region. The extensive data set collected will also be employed to evaluate and improve air quality forecast models.

The Air Quality Research Subcommittee (AQRS) of the Committee on Environment and Natural Resources (CENR) provides interagency collaboration at the U.S. Federal level. NOAA co-leads the AQRS. On the broader international arena, the coordi-

nating body is the North American Research Strategy for Tropospheric Ozone (NARSTO), a tri-lateral public/private partnership focused on ozone and particulate matter research in the U.S., Canada, and Mexico.

PSD and CSD use their suite of remote sensors, including a mobile profiler network, airborne and ground-based ozone Lidars, Doppler Lidar, and supporting turbulence instrumentation to understand and better model the transport, transformation, and fate of primary and secondary pollutants in both rural and urban environments as well as in complex orography. PSD and CSD participated in field programs in FY 2002 designed to develop a deeper understanding of climate variability and source pollutants in the New England region, and to investigate the composition of air masses along the Pacific coast of North America as part of the Intercontinental Transport and Chemical Transformation (ITCT) program. ITCT is a coordinated international research program designed to address the question, "How does the transport of chemicals from one continent influence the air quality in other continents, as well as regional and global climate?" PSD and CSD will be deploying a number of lidar systems and wind profiler radars in support of these programs. In 2005, GMD added high resolution ozone profile measurements to seven light aircraft instrument packages that are flown on weekly/bi-weekly greenhouse gas sampling profiles across the continental U.S. Within two years ozone instruments will be added to an additional 14 profiling aircraft. This data will be evaluated for possible integration into air quality and ozone forecast models.

The National Ocean Service (NOS) monitors, assesses, and forecasts conditions in the coastal and oceanic environment to maintain a healthy, safe, and economically productive coastal and oceanic environment for present and future generations. NOS is the primary civil agency within the Federal government responsible for the health and safety of our nation's coastal and oceanic environment. Largely through the Tides and Current Program line, NOS acquires water levels, currents, winds, and other physical oceanographic and meteorological data, and distributes these data and circulation predictions as elements of an integrated NOS program to provide a comprehensive science-based suite of information products required by the marine transportation community to ensure safe and efficient marine transportation, including the transport of oil and other hazardous materials. NOS also provides coastal oceanographic and meteorological products required by the National Weather Service (NWS) to meet its short-term weather and forecasting responsibilities, including tsunami and storm surge warnings. NOS manages several observing systems and programs, however four in particular are heavily linked to the capability of NOAA to meet weather and water needs of the nation.

NATIONAL WATER LEVEL OBSERVATION NETWORK (NWLON)

NOS manages the NWLON, 200 stations located along the coasts of the U.S. and the Great Lakes, from which water level data, as well as other oceanographic and meteorological data, are collected and disseminated. NWLON provides a number of NOAA and other Federal programs with data and supporting information, such as the NOAA Nautical Charting Program, NWS Tsunami Warning System, NWS storm surge warning/forecast activities, and the Climate and Global Change Program. An event triggered or manually triggered NWLON modification is now operational that allows emergency "Tsunami Warning" GOES transmissions to NWS when the water level exceeds a specified high/low limit or when the rate of change between the standard 6-minute water level values exceeds a specified value. A similar event triggered modification is also operated for the NWS storm surge warning program when expected elevations are predicted or observed during coastal storms and hurricanes.

This capability for high-rate data has recently been enhanced at many stations by the introduction of 6-minute interval GOES transmissions. Although not all NWLON stations are presently equipped with meteorological sensors, an increasing number of stations are each year. Water level and meteorological data are automatically formatted into bulletin format for inclusion into the NOAA AWIPS pipeline.

PHYSICAL OCEANOGRAPHIC REAL-TIME SYSTEM (PORTS®)

PORTS® is a decision support tool which improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS® measures and disseminates observations and predictions of water levels, currents, salinity, and many meteorological parameters, e.g. winds, barometric pressure, and visibility, needed and requested by the mariner to navigate safely. Highway and railroad bridge mounted "Air Gap" sensors for water level detection are presently being developed and are included in future plans for PORTS®.

The 13 existing PORTS® systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. PORTS® are partnership programs in which local operating partners fund the installation and operation of the measurement systems. The largest of NOS's existing installations is comprised of over 26 separate instruments. The smallest consists of a single water level gauge and associated oceanographic and meteorological instruments, i.e. winds, barometric pressure, etc. (Figure 3-DOC-37).

Regardless of its size, each PORTS® installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting U.S. ports. In addition, prevention of maritime accidents is the most cost effective measure that can be taken to protect fragile coastal ecosystems. One major oil spill, e.g. EXXON VALDEZ, can cost billions of dollars and destroy sensitive marine habitats critical to supporting coastal marine ecosystems. PORTS® provides information to make navigation safer, thus reducing the likelihood of a maritime accident, and also provides the information necessary to mitigate the damages from a spill, should one occur. An extensible PORTS® can be integrated with other marine transportation technologies such as Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS).

NATIONAL OPERATIONAL COASTAL MODELING PROGRAM (NOCMP)

NOCMP serves a variety of users with oceanographic nowcast forecast products for ports, estuaries and the Great lakes. The integration of PORTS® technology and numerical circulation models allows nowcasts and predictions of parameters within the boundaries of the models even at locations where physical measurements are not available. The Chesapeake Bay Oceanographic Forecasting System

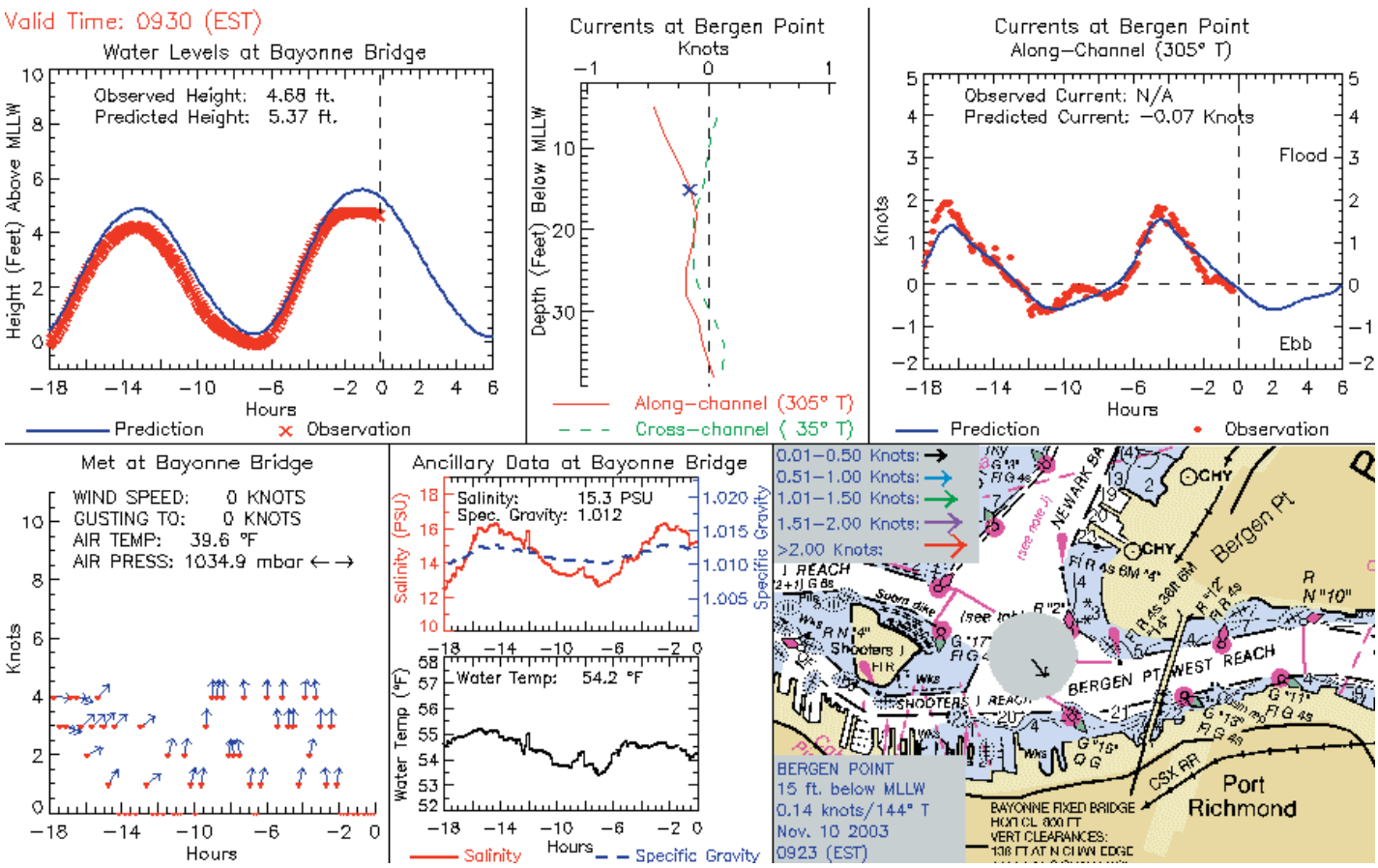


Figure 3-DOC-37. New York/New Jersey PORTS: Bergen Point Composite.

(CBOFS) is an NOS project that provides forecasts of total water level within the Bay in addition to the astronomical tidal prediction. The New York/New Jersey Harbor nowcast/forecast model came on line in 2003, followed by a Houston/Galveston Bay nowcast/forecast model in 2004. Newer models include the St. Johns River, FL and the Great Lakes. In cooperation with OAR and NWS, the NOS CO-OPS now runs 5 models as part of the Great Lakes Operational Forecast System (GLOFS) providing forecast guidance for water level, wind, currents and water temperature. Also, ongoing research will enable PORTS® or similar systems to incorporate biological and chemical sensor systems and forecast models as required and integrate the information with circulation measurements to provide information on transports of materials in the ecosystem essential for effective marine resource management and homeland security.

NOS CONTINUOUS REAL-TIME MONITORING SYSTEM (CORMS)

CORMS was designed to operate on a 24hour/7 days a week basis to ensure the accuracy and working status of tide and current observations acquired via the NWLON and PORTS® programs. CORMS improves the overall data quality assurance of real-time measurements, reduces NOAA's potential liability from disseminating inadequate data, and makes the observations more useful for all applications. CORMS ingests real-time data from all field sensors and systems, including the operational nowcast/forecast models, determines data quality, and identifies and communicates the presence of invalid or suspect data to real-time users/customers who rely on the data (Figure 3-DOC-38). CORMS is especially vigilant during storm and tsunami events to ensure the full set of products and services is being disseminated in a timely fashion. An advanced version of this system, CORMS AI, is presently in developmental stages.

Figure 3-DOC-38. PORTS sites in the New York and New Jersey linked by CORMS.

NOAA Marine and Aviation Operations (NMAO) operates a wide variety of specialized ships and aircraft to support NOAA mission goals. NOAA's ship fleet includes oceanographic and atmospheric research vessels. NOAA's aircraft fleet includes aircraft that collect environmental and geographic data essential to NOAA hurricane and other severe weather and atmospheric research; and aircraft that conduct aerial surveys for hydrologic research for forecasting flooding potential from snow melt.

Figure 3-DOC-40. NOAA Ship KA'IMIMOANA

NOAA SHIPS SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA Ship *RONALD H. BROWN* (Figure 3-DOC-39), an oceanographic and atmospheric research platform, is the largest vessel in the NOAA fleet (274 feet). With its instruments and sensors, *RONALD H. BROWN* travels worldwide supporting scientific studies to increase our understanding of the world's oceans and climate. An advanced meteorological scientific Doppler radar makes the ship a unique attribute to the research fleet.

NOAA Ship *KA'IMIMOANA* (Figure 3-DOC-40) primarily supports the research programs of NOAA's Tropical Atmosphere Ocean (TAO) Project (real-time data from moored ocean buoys for improved detection, understanding and prediction of El Niño and La Niña). These research programs are designed to improve our understanding of the role of the tropical ocean in the world's climate. The ship deploys, recovers, and services deep sea moorings that measure ocean currents, ocean temperatures, and atmospheric variables, throughout the equatorial Pacific Ocean. In addition to data from these moorings, the ship measures upper ocean currents, surface salinity, carbon dioxide content, and takes upper air atmospheric soundings while underway.

The *RONALD H. BROWN* and *KA'IMIMOANA* annually support the Tropical Atmospheric Ocean (TAO) Array by servicing approximately 60 ATLAS and current meter moorings in the central and eastern equatorial Pacific.

In FY 2007, the *RONALD H. BROWN* will work in cooperation with the Woods Hole Oceanographic Institute to conduct mooring recovery and deployment operations of the Stratus Ocean Reference Station (the sixth setting) under the stratocumulus clouds off Chile and Peru. The ship will conduct meteorological and air-sea flux observations to document and establish the accuracy of the moored metrological observations, and to observe the oceanic and atmospheric variability. This region is of critical importance to climate predictability. Additionally, during the project the *RONALD H. BROWN* will support the Chilean Navy in the recovery and deployment of a DART (Tsunami) mooring.

The *RONALD H. BROWN* will again conduct the African Monsoon Multi-

Figure 3-DOC-39. NOAA Ship RONALD H. BROWN

disciplinary Analysis study in FY 2007 to improve understanding of the West African monsoon and its influence both on the regional environment as well as its role in Atlantic Tropical cyclone development. In addition, the ship will be conducting a CO2 tracer study along the East Coast of the U.S..

In FY 2007, the *RONALD H. BROWN* will work with the Woods Hole Oceanographic Institute to conduct mooring deployment (seventh setting) and recovery operations of the Northwest Tropical Atlantic Station located approximately 500NM southwest of Barbados. Data will be simultaneously logged between the sixth and seventh mooring and the ships meteorological suite during several hour long inter-comparison periods.

NMAO supports the National Data Buoy Center (NDBC) on an as-needed basis in the recovery of meteorological and environmental monitoring buoys that have been disabled or become adrift. In FY 2005, NMAO diverted four ships for a total of 20 sea days in support of NDBC buoy recoveries. In FY 2006, NMAO will continue to provide support to NDBC for recovery of buoys that come adrift as necessary when ship schedules permit.

NOAA AIRCRAFT SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA aircraft support a broad range of meteorological activities and projects with its fleet of aircraft based at MacDill Air Force Base in Tampa, Florida. Three of its eleven aircraft are dedicated to this purpose throughout the year, providing valuable information to NOAA and the nation.

For these three aircraft, the 2005 hurricane season was the busiest on record. Operating from bases in Florida, Georgia, Costa Rica, the U.S. Virgin Islands and Barbados, the NOAA Gulfstream G-IV (SP) and two WP-3D Lockheed Orion aircraft flew 123 missions for a total of 897 hours. The data collected and transmitted from these aircraft during the season made a significant positive impact on hurricane forecasts and warnings during Hurricane Dennis, Emily, Katrina, Ophelia, Rita and Wilma.

The NOAA Gulfstream, G-IV (SP) (N49RF), provides scientists with a platform for the investigation of processes in the upper troposphere and lower stratosphere (Figure 3-DOC-41). With an operating ceiling of 45,000 ft, the G-IV (SP) is a critical tool for obtaining the data necessary to improve hurricane and winter storm track forecasts and for research leading to improvements in hurricane intensity forecasts. The G-IV (SP) is also being used for air chemistry studies where a high altitude capability is required. In 2006, researchers studying the role of Saharan dust on tropical storm development and intensity also used this aircraft.

The NOAA G-IV (SP) annually supports Hurricane Synoptic Surveillance missions where the aircraft flies in the environment surrounding the storm at a high altitude releasing GPS dropsondes at pre-selected locations (Figure 3-DOC-42). The data from these vertical atmospheric soundings are transmitted from the aircraft to the NCEP computer site where they are incorporated into the hurricane computer models to improve hurricane track forecasts. The dropsonde directly measures temperature, pressure, and humidity as it falls through the atmosphere to the surface, and computes wind speed and wind direction using a full-up GPS receiver.

Recent estimates of the improvement in hurricane track predictions utilizing this aircraft and dropsonde are between 20 and 30 percent, resulting in a savings of $10 million or more per hurricane in warning and preparedness costs. In 2005, the 48-hour improvement in track forecasts for Hurricanes Katrina and Rita were 40 and 30 percent respectively.

The NOAA G-IV (SP) also annually supports the Winter Storms Reconnaissance Program in an effort to improve forecasts released 24 to 96 hours before winter storms in the U.S.. This aircraft, in conjunction with the Air Force Reserve's WC-130s, utilize the GPS dropsondes to collect data on developing severe winter storms over the Pacific Ocean that will seriously impact the continental U.S. and Alaska. During one month of the two-month season, both aircraft operate in tandem, one from Alaska and the other from Hawaii, to collect data both north and south of the jet stream simultaneously. General improvement in forecast accuracy of up to 20 percent has already been seen, and even higher percentage improvements on individually targeted events have been realized from this program. Typically, during the final month of the program, the NOAA G-IV (SP) operates independently from either the base in Alaska or Hawaii as the case may dictate.

A recent additional mission for the

Figure 3-DOC-41. NOAA Gulfstream G-IV (SP)

G-IV (SP) was the support of the Saharan Air Layer Experiment (SALEX). The outbreaks of dry Saharan dust has been shown to have a dampening effect on the development of tropical cyclones in the Atlantic, and the G-IV (SP), with its high altitude and dropsonde capabilities, is the ideal tool to study this phenomenon. Operating from Barbados, the most easterly island in the western Atlantic, this aircraft flew four missions in 2005 on an initial study of the dust outbreaks, and

it returned to Barbados in 2006, along with a NOAA WP-3D aircraft, to continue this important work.

NOAA's Aeronomy Lab, located in Boulder, CO, is presently expanding its air chemistry capabilities on the G-IV (SP) beyond just ozone measurements with the addition of a proton transfer reaction mass spectrometer (PTR_MS). The PTR_MS provides in-situ measurements of volatile organic compounds (VOCs). A second instrument, which measure carbon monoxide (CO), is also being tested aboard the aircraft. Beyond just their dedicated research, lab scientists also hope to piggyback on missions during the 2006 hurricane season.

NOAA's atmospheric and oceano-

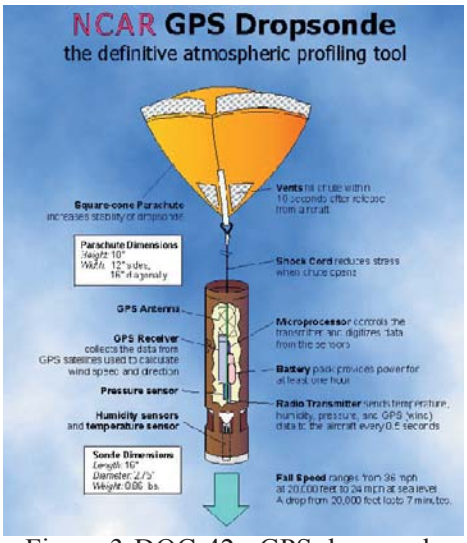


Figure 3-DOC-42. GPS dropsonde

graphic research, as well as its reconnaissance operations, is supported by two WP-3D Lockheed Orion aircraft (N42RF and N43RF) which carry a full array of state-of-the-art environmental research instrumentation (Figure 3-DOC-43). The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. NOAA's Aircraft Operations Center (AOC) develops and calibrates specialized instruments, integrates user-supplied instrumentation into its automated data recording systems, and processes and analyzes data sets collected during various field programs.

The AOC WP-3D aircraft, while executing the complex patterns for hurricane research, also provided storm data to the National Hurricane Center (NHC) in near, real-time, transmitting flight level data, GPS dropsonde messages, as well as radar images via its multiple aircraft-satellite data links. With the Stepped Frequency Microwave Radiometers (SFMR) coming online operationally during FY 2005, increasing emphasis has been placed on utilizing the NOAA WP-3Ds to map the surface wind fields in and around hurricanes and tropical storms. Real-time surface wind speed maps are critical to providing more accurate forecasts of the extent of hurricane and storm force winds.

The AOC aircraft also augment the Air Force Reserve reconnaissance aircraft during particularly active storm periods when tasking requirements exceed their available resources.

Each year, one of the NOAA WP-3Ds participates in a Hurricane Awareness Tour targeting, alternately, the Gulf and East coast regions of the U.S., those areas that are most vulnerable to land-falling storms. This educational outreach effort is directed at both middle-grade school children, the age group most likely to see, learn and convey a message home, as well as the general public. These tours are operated in concert with the participation of officials from the NHC, the Red Cross, FEMA and other local and state emergency management personnel. This is becoming an increasingly more popular and successful venture as coastal populations grow and the threat of an increasing number of storms place more people in harm's way.

During the 2005 season, the two NOAA WP-3Ds supported three major research experiments. In support of NOAA's Hurricane Research Division, these aircraft participated in the Intensity Forecast Experiment (IFEX), a multi-year endeavor to study the life cycle of hurricanes from pre-depression to mature land-falling stage in order to better characterize their structure and dynamics with the objective of improving intensity forecasts. During the 2005 season, the NOAA research team was fortunate to obtain complete life cycle data sets on five hurricanes, Dennis, Emily Katrina, Ophelia and Rita. While some effort will be made during the 2006 season to continue these observations, the major emphasis will be shifted to a study of the impact of Saharan dust on the development of tropical storms.

In collaboration with NASA and its


Figure 3-DOC-43. NOAA WP-3 Orion

ER-2 aircraft, NOAA utilized the two WP-3Ds in support of the Tropical Cloud Systems and Processes (TCSP) study. In an experiment that focused mostly on the genesis of tropical storms, the two aircraft were based for a three-week period in Costa Rica, flying missions in the Caribbean, Gulf of Mexico and eastern Pacific in concert with the ER-2 aircraft.

Following TCSP, NOAA scientists used the two WP-3Ds in collaboration with scientists from NSF's National Center for Atmospheric Research (NCAR) and the Naval Research Laboratory (NRL) in a second major hurricane research experiment in August and September. The Hurricane Rainband and Intensity Change Experiment (RAINEX) was a project focusing on the role that rainbands play in changes to storm intensity. The uniqueness of this experiment, which utilized the Tail

Doppler radars from the two NOAA WP-3Ds and the ELDRA Tail Doppler radar on the NRL P-3, was the satisfactory fulfillment of the requirement to provide flight track data and lower fuselage radar imagery from the two NOAA aircraft to the NRL P-3 at a frequency of at least once every 15 minutes.

Pilots on the NRL P-3 aircraft, which was operating with only forward-looking nose radar, required this information in order to safely and effectively operate in the hurricane environment with the NOAA aircraft. This was accomplished utilizing high-speed satellite communications to stream radar imagery and flight level data from the NOAA aircraft to ground computers where it was reformatted and transmitted to the NRL aircraft. Because of the success of this effort, valuable data sets were obtained in Hurricanes Katrina, Ophelia and Rita.

Tropical to extra-tropical transition was the focus in Hurricane Ophelia as one of the NOAA WP-3Ds flew several missions into that storm as it moved northward over the cooler waters of the north Atlantic during the middle of September, 2005. Operating initially from MacDill AFB in Tampa, FL, and later from Pease Air Base in Portsmouth, NH, N42RF flew several missions as far north as Canadian airspace east of Nova Scotia collecting data for one of HRD's research objectives, that being the decay of tropical systems to an extra-tropical state over cooler water.

The NOAA WP-3Ds annually support both a summer and winter operation in support of a NESDIS satellite validation program. Operating in regions of high winds and heavy precipitation, one of the WP-3Ds, equipped with microwave scatterometers and radiometers, provide flight validation of NOAA QuickScat and WindSat sensed ocean surface wind vectors. Traditional venues for these operations are Alaska or Newfoundland in the winter and the Atlantic and Caribbean regions during the summer hurricane season.

Every other year, one of the NOAA WP-3Ds participates in an intensive air chemistry program, usually in concert with a number of other Federal agencies and universities. During July 2004, N42RF participated in the New England Air Quality Study (NEAQS) along with a number of other aircraft, ground stations, and the NOAA Ship *RONALD H. BROWN*. During the summer of 2006, N43RF is scheduled to join several other aircraft operating in the Houston area and the *RONALD H. BROWN* operating in the Gulf of Mexico in the Texas Air Quality Study. Packed completely with an impressive array of in-situ chemical samplers and three instrument pods mounted beneath its wings, the aircraft will take measurements of a wide range of chemical constituents at low altitudes over the urban and rural landmass as well as the marine boundary layer. Additionally, atmospheric profiles were made from the surface to the maximum altitude capability of the aircraft (~25,000 ft).

During FY 2006, one of the NOAA WP-3Ds completed the Atmospheric Rivers Project over the Pacific northeast of the Hawaiian Islands. As part of the NOAA's weather-climate program, this project focused on documenting the flow of moisture moving is a northeasterly direction toward the U.S. mainland - measurements that are critical to both the global water cycle and to storm prediction.

A NOAA AC-695A Commander 1000 (N45RF) and a NOAA AC-500 Shrike (N51RF) are used annually to conduct important snow pack surveys in the northern and western continental U.S., Alaska, and southern Canada (Figure 3-DOC-44). During these survey flights, the gamma radiation sensors aboard these aircraft measure the naturally occurring terrestrial radiation emitted from the ground to obtain snow water-equivalent estimates. This data is transmitted to the National Operational Hydrologic Remote Sensing Center (NOHRSC) up to three times a day from each aircraft, and after further processing the data is distributed to NWS field offices within five minutes of receipt from each aircraft. These data are used by the NWS to forecast river levels and potential flood events resulting from snowmelt water runoff. Hydroelectric power interests and other water supply managers also use the data to regulate water storage and delivery.

Figure 3-DOC-44. NOAA JetProp Commander - N45RF.